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EXPERIMENTAL PERFORMANCE OF TWO SEGMENTED WALL MAGNETOHYDRODYNAMIC ELECTRIC POWER GENERATORS

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ARO, Inc.

January 1967

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ROCKET TEST FACILITY

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NOTICES

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FOREWORD

The test program reported herein was conducted at the request of the Aeronautical Systems Division (ASD), Air Force Aero-Propulsion Laboratory (AFAPL), Air Force Systems Command (AFSC), Wright-Patterson Air Force Base, Ohio for the University of Tennessee Space Institute (UTSI) under Program Element DOD 625-0301R.

The results of the test were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF33(615)-2691. The test was conducted in Propulsion Research Area (R-2C-4) of the Rocket Test Facility (RTF) under ARO Project No. RW0541, and the manuscript was submitted for publication on November 2, 1966.

Information in this report is embargoed under the Department of State International Traffic in Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Government subject to approval of Air Force Aero-Propulsion Laboratory (APIE-2), or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.

This technical report has been reviewed and is approved.

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ABSTRACT

A test program was conducted for the University of Tennessee Space Institute on a vertically segmented wall (Hall) and a diagonally segmented wall (45-deg) magnetohydrodynamic generator. The generators were 48 in. in length and had inside dimensions of 2 in. in width, diverging from 4 in. in height at the channel inlet to 6 in. in height at the channel exit. The plasma was provided by a gaseous oxygen/RP-1 combustor with a Mach number 1.6 nozzle. The propellants were seeded with potassium hydroxide dissolved in ethyl alcohol to produce a high ion concentration in the exhaust stream. The generated power was dissipated through a resistor load bank with a variety of parallel and series resistance configurations. Operating conditions varied as follows: combustor chamber pressure = 39 to 48 psia, KOH concentration to 1.3 percent of total propellant weight flow, magnetic field to 20,000 gauss, and load bank resistance from 2.5 to 27 ohms. Tabulations of combustor performance and of the electrical, pressure, and temperature data from the two generator configurations are presented.

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SECTION I
INTRODUCTION

A magnetohydrodynamic (MHD) electric power generator is classed as a direct energy conversion device. Ionized gas flowing at high velocity through a channel is acted on by a transverse magnetic field to produce an electromotive force (EMF) perpendicular to the velocity vector and the magnetic field vector. The same physical principles are involved in an MHD generator as in a conventional generator except that conducting gases replace the current carrying conductors of the rotor.

The University of Tennessee Space Institute (UTSI) is currently engaged in a research investigation of parameters governing the performance of open cycle MHD devices. The program is designed to provide correlation between theoretical and experimental performance of several types of MHD generators in order to establish basic generator design criteria. The scope of the experimental effort includes a parametric study to optimize the performance of 45-, 60-, and 75-deg slanted, Hall, and Faraday generator channels operating at various gas dynamic conditions, electrical loads, and magnetic fields. The walls of each of the channels will be segmented to reduce the effect of the Hall field.

The test program reported herein was conducted in Propulsion Research Area (R-2C-4) of the Rocket Test Facility (RTF). The RTF personnel were responsible for design and fabrication of the combustor with associated propellant, instrumentation, and exhaust systems. The channels, magnet, diffuser, load banks, and electrical meters were supplied by UTSI.

This report presents the data obtained from the vertically segmented wall (Hall) and the diagonally segmented wall (45-deg) MHD generator phases of testing. A description of the combustor, channels, magnet, and associated systems is given, and the methods used to obtain the required measurements are presented.

SECTION II
APPARATUS

2.1 TEST ARTICLE

The test article consisted of a combustor, an MHD channel and diffuser, a magnet, and supporting systems. These components are described in detail in the sections to follow.

2.1.1 MHD Generator

Two MHD generator channels (Figs. 1 through 3, Appendix I) were employed: a diagonally segmented wall (45-deg) channel and a vertically segmented wall (Hall) channel.

The copper channels were nominally 48 in. long with outside dimensions of 3.75 in. wide by 8 in. high. The inside dimensions were 2 in. wide by 4 in. high at the inlet with the side walls parallel and the top and bottom walls diverging to 6 in. high at the exit. The 36-in. active portions of the channels (conforming to the 36- by 6-in. magnetic field cross section) were assembled from several individually insulated wall segments, each segment acting as an electrode. The remaining 12 in. of the channel lengths (nominally 6 in. at each end) was made of copper blocks (transition elements) insulated from each other to reduce eddy current effects. Four ceramic-insulated, stainless steel rods running lengthwise internally at the four corners of the channel held the channel elements in longitudinal compression. In addition, each element and block was attached to the adjacent elements or blocks by ceramic-insulated, stainless steel screws.

The 45-deg channel segments (Fig. 2) were 0.417-in.-thick copper slabs electrically insulated from each other by 0.018-in.-thick mica paper. The segments were inclined forward at 45 deg to the channel axis to form a laminate array 40 in. long, of which 2 in. at each end was part of the inactive portions (outside the volume between the 6- by 36-in. magnet pole faces) of the channel. The remaining 4 in. at each end was composed of insulated copper blocks (transition elements). Each of the 50 full segments was split at the middle to form a top and bottom element, also insulated from each other by 0.018-in.-thick mica paper. These elements and the 16 partial end segments comprised the electrodes.

The Hall channel segments (Fig. 3) were 0.582 in. thick and arranged perpendicular to the axis of the channel. The segments of the Hall channel were split at the middle and insulated similar to the 45-deg channel. The 60 segments, with insulation, comprised the 36-in. active length of the Hall channel; the remaining 6 in. at each end was composed of insulated copper blocks (transition elements).

The diffuser (Fig. 4) was made from 1/4-in. stainless steel, rectangular in cross section, diverging from 2 by 6 in. at the channel attachment flange to 4 by 8-1/2 in. at the discharge plane over a length of 24-1/2 in. The diffuser adapts to the forward bulkhead of the spray chamber with a rubber slip joint seal and extends 8 in. into the spray

chamber. A 5-probe water-cooled pressure rake (Fig. 5) was installed in the diffuser for measuring exhaust gas total pressure.

2.1.2 Magnet

The magnetic field was provided by a 20, 000-gauss electromagnet (Fig. 6) and was directed normal to the vertical plane containing the axis of the channel. The distance between the magnet pole faces was 3. 96 in; each face was 6 in. high by 36 in. long.

The magnet is of "C" frame construction with eight strip-wound coils, six coils having 48 turns each and two coils having 55 turns each (Fig. 6c). Each coil is designed to conduct 600 amp for a total of 238, 000-amp turns. The magnetic field strength is presented in Fig. 7 as a function of input current. Water cooling coils were installed adjacent to, but insulated from, the electrical coils. Cooling water was supplied at a rate of 50 to 60 gal/min at a nominal inlet pressure of 70 psig. In case of accidental power failure, the energy stored in the magnetic field is dissipated through a 0. 040-in. spark gap located in the electrical terminal box (Fig. 6a).

Electric power to the magnet was supplied by fifteen, 400-amp, 40-v, d-c power supplies connected in five parallel arrays of three each in series (Fig. 8).

2.1.3 Load Bank

The electrical power generated by the MHD channels was dissipated as heat through four air-cooled load banks, each containing 252 heater element resistors (Fig. 9). Each load bank is capable of dissipating 100 kw. The individual resistors are strapped to form the desired parallel and series arrangements for impedance matching to the channel electrical output.

2.1.4 Combustor

Ionized gas to the MHD generator was provided by a gaseous oxygen (GO_2)/RP-1 combustor (Fig. 10) operating at chamber pressures ranging from 39 to 48 psia and at a nominal oxygen-to-fuel ratio of 2. 8. A seeding agent consisting of a solution of potassium hydroxide (KOH) saturated in MIL-A-6091 ethyl alcohol (21-percent KOH by weight) was injected into the RP-1 upstream of the combustor to increase the exhaust gas electrical conductivity.

The propellants were injected into the chamber through a 0. 9-in.-thick, stainless steel injector (Fig. 11). The RP-1/seed solution was

injected through 0.04-in.-diam orifices located on radii of 0.63 in. (four orifices) and 2.75 in. (eight orifices) on the injector face. The RP-1 was injected axially through the inner ring orifices and inward at an angle of 30 deg to the combustor centerline through the outer ring orifices. The GO_2 was injected through fifty 0.22-in.-diam orifices located on three concentric rings between the inner and outer RP-1/seed spray rings. Combustor chamber pressure was measured through an orifice in the injector face.

The 7.0-in.-diam by 14.0-in.-long water-cooled combustion chamber was fabricated from 347 stainless steel. The chamber cooling water flow rate was nominally 30 lb_m/sec, which provided a water velocity through the cooling passage of 17 ft/sec and a water temperature rise during firing of approximately 7°F.

The water-cooled, stainless steel exhaust nozzle (Fig. 12) was bolted to the downstream end of the cylindrical combustion chamber. The circular-to-rectangular cross-sectional transition is accomplished in the converging subsonic nozzle section upstream of the throat. The contoured supersonic section diverges from 2.0 by 3.1 in. at the throat to 2.0 by 4.0 in. at the exit, providing an area ratio of 1.37 and a nominal exit Mach number of 1.6. The nozzle cooling water flow rate was 35 lb_m/sec, which provided a water velocity at the throat of 33 ft/sec with a water temperature rise during firing of approximately 5°F.

Engine ignition was provided by a hydrogen-air igniter assembly (Fig. 13). The hydrogen-air mixture was ignited by a spark plug and exhausted into the chamber through the center port of the injector. The total flow rate of the igniter reactants was approximately 0.11 lb_m/sec, and the air-to-fuel ratio was nominally 16.

2.2 INSTALLATION

The combustor, magnet, channel, and diffuser were installed in Propulsion Research Area (R-2C-4). A photograph and a schematic of the installation are shown in Fig. 14. The combustor was mounted on a support stand and connected to the facility propellant and coolant systems. The magnet was installed on the magnet support stand, and the channel was placed on a support stand between the magnet pole faces. The forward flange of the channel was aligned with and bolted to the combustor nozzle flange. The channel diffuser extended through the forward bulkhead of a spray chamber, which contained one air spray ring and four water spray rings. A 12-in. exhaust duct was bolted to

the downstream end of the spray chamber to direct the cooled exhaust gases into the facility exhaust ducting to be discharged into the atmosphere.

The spray chamber (Fig. 15) is a 36-in.-diam, 10-ft-long cylinder made of 1/4-in. mild steel. The air spray ring is located just forward of the diffuser exit plane (Fig. 14b) and provides a nonconducting shroud around the ionized exhaust gases to prevent electrical conduction to the spray chamber walls until the exhaust gases are cooled below the ionization temperature. The four water spray rings cool the exhaust to a low temperature before it enters the exhaust duct and is exhausted to the atmosphere. The spray chamber is insulated against 2000-v potential from ground, and the supply lines and drain line are made of cotton braid rubber hose. The resistance to ground through the lines is about 1000 ohms with the 6-in. drain line full of cooling water.

2.2.1 Electrical

Figures 16 and 17 show typical electrical circuits used for the 45-deg and the Hall channels, respectively. The electrical measurements made were (1) voltage across the load resistors, (2) current from channel electrodes to the load bank, and (3) current from the channel element top-to-bottom. These electrical measurements involved the lettered partial end segments and the odd-numbered full segments of the 45-deg channel. The even-numbered full segments were shorted top-to-bottom and were not connected to the load bank. In the Hall channel, the even-numbered segments 8 through 52 were shorted top-to-bottom, and the odd-numbered segments 9 through 51 were shorted top-to-bottom through ammeter shunts. Only segments 1 through 7 and 53 through 60 were electrically connected to the load bank and equipped with ammeters for measurement of channel-to-load bank current and element top-to-bottom current. Current from the four segments at the upstream end and the four segments at the downstream end of each channel to the load bank was carried by 3/0 cable, and current from element top to element bottom and from element to load bank for all other segments was carried by No. 2 AWG 600-v cable.

The shunt panel (Fig. 18) is an electrical interface between the channel and the load bank, containing low resistance (0.0005-ohm) shunts across which current between channel elements and between the channel and load bank is measured. Voltage taps and fuses to protect the meter circuits and load bank circuits are also provided in the shunt panel.

2.2.2 Propellant System

A schematic of the propellant system is shown in Fig. 19. The GO_2 was supplied from a 55,000-scf trailer charged at pressures ranging to 2200 psia. The pressure was reduced and maintained at a value which provided the desired flow rate by an automatic pressure control system. Oxygen flow rate was determined from a critical flow venturi located downstream of the pressure control system.

The RP-1 flow was supplied by and controlled from a 75-gal stainless steel tank pressurized with dry nitrogen. The pressure-fed alcohol-KOH seeding agent was injected into the RP-1 line upstream of the engine injector. All propellant systems incorporated provisions for purging the lines with dry nitrogen.

2.3 INSTRUMENTATION

Instrumentation was divided into two distinct groups - engine and spray chamber instrumentation (herein designated support equipment instrumentation) and channel and magnet instrumentation. Instrument ranges, recording methods, and system accuracies for all measured parameters are presented in Table I (Appendix II).

2.3.1 Support Equipment Instrumentation

Instrumentation was provided to measure combustor chamber pressure, injector pressures, propellant and seed flow rates, propellant tank pressures, combustor chamber and nozzle cooling water temperature rise, and spray chamber pressure.

Bonded strain-gage-type transducers were used to measure pressures. Copper-constantan thermocouple probes were used to measure cooling water inlet and discharge temperatures and iron-constantan probes to measure propellant temperatures. Fuel and seed flow rates were measured with turbine-type flowmeters. The GO_2 flow rate was determined by a critical flow venturi measuring device.

The output signal of each measuring device was recorded on independent instrumentation channels. Primary combustor data were obtained from two combustion chamber pressure channels (one 50- and one 100-psia), one oxygen venturi upstream pressure channel, two injector pressure channels (oxygen injector and fuel injector), two fuel flow channels, and one seed flow channel. The primary data were recorded as follows: Each pressure output signal was sent to a millivolt-to-frequency converter. A magnetic tape system, recording in frequency

form, stored the signal from the converter for reduction at a later time by an electronic digital computer. The computer provided a tabulation of average absolute values for each 0.2-sec time increment. The fuel and seed flow signals were sent through wave shaping converters to the magnetic tape systems. A photographically recording, galvanometer-type oscillograph, recording at a paper speed of 10 in./sec provided an independent backup of all primary instrumentation channels. The secondary data were recorded on magnetic tape from a multi-input, high-speed, analog-to-digital converter at a scan rate for each channel of 75 times/sec. Playback of this tape on the IBM 7074 computer provided a tabulation of average absolute values for each 0.2-sec time increment.

2.3.2 Channel and Magnet Instrumentation

Instrumentation was provided to measure channel wall pressures, channel temperatures (Fig. 20), generated voltages and currents, and magnet input power. Channel wall pressures were measured using bonded strain-gage-type transducers (0- to 30-psia). Chromel®-Alumel® (CA) thermocouples were imbedded in copper slugs which were press fitted into holes in the channel segments to locate the thermocouple junctions approximately 1/4 in. from the inside channel surface.

The output signal of each channel pressure transducer was recorded on magnetic tape from a multi-input, high-speed, analog-to-digital converter at a scan rate for each output signal of 75 times/sec. Playback of this tape on the IBM 7074 computer provided a tabulation of average absolute values for each 0.2-sec time increment. Use of this equipment was made possible by using electrically nonconducting tubing from the high potential channel to the ground potential transducers.

Channel temperatures, generated voltages and currents, and magnet input voltage and current were displayed on an array of meters located on a rack-mounted meter panel (Fig. 21) and insulated for 2000-v potential to ground. The data from these meters were recorded photographically by a 70-mm camera, which was timer actuated to provide photographs at approximately 1-sec intervals during a power generation firing. These photographs were time correlated with engine burn time by "camera pulses" recorded on the oscillograph.

SECTION III
PROCEDURE

Initial combustor checkout and calibration firings were accomplished in preparation for generator runs using a water-cooled 5-in.-diam carbon steel pipe in place of the channel and diffuser.

The assembled MHD channels were received at AEDC on November 18, 1965 (45-deg), and January 17, 1966 (Hall). The channels were installed for nonpower aerodynamic behavior studies and system checkout. The magnet was then installed, and calibration runs were made to determine field uniformity at various magnet current settings.

Power generating runs were made for a variety of magnetic field strengths, electrical loads, and seed flow rates.

Observation of measured channel pressure variation and post-fire inspection of the channel during the early portion of the program indicated that the channel pressure taps were susceptible to becoming clogged with unburned seed residue. Therefore, the pressure measuring systems were periodically checked by evacuating the channel to -2 psig while recording the indicated internal pressure variation during pumpdown. Figure 22 shows the indicated pressure variation for clear, partially restricted, and fully restricted taps.

SECTION IV
RESULTS AND DISCUSSION

Two MHD electric power generator channel configurations were tested to determine the effect on generator performance of variations in external resistance loading, magnet field strength, and seed concentration. The products of combustion from a GO_2/RP-1 combustor seeded with a solution of potassium hydroxide saturated in ethyl alcohol were supplied to the generator inlet at a Mach number of 1.6 and at total pressures ranging from 39 to 48 psia. The diffuser exhaust pressure was approximately atmospheric for all firings. The channel pressures ranged from atmospheric during power generating runs to 11 ± 2 psia during nongenerating runs.

This report documents in tabular form the measured values of combustor chamber pressure and propellant flow rates, generator resistance loading, channel internal pressures, typical variations in channel temperature during firing, and generator electrical currents

and voltages. The conditions at which performance data were obtained are summarized in Table II. Data from 52 firings are included; 34 firings were made with a diagonally segmented wall (45-deg) channel, and 18 firings were made with a vertically segmented wall (Hall) channel configuration. Also presented are the combustor operating characteristics and a discussion of the channel structural durability.

4.1 COMBUSTOR OPERATING CHARACTERISTICS

The analog variations in chamber pressure, propellant flow rates, and injector pressures during a typical engine ignition are shown in Fig. 23. Also shown is the camera pulse trace which relates the time when generator electrical and temperature data were photographically recorded with combustor operational events. The times required for the RP-1 and the seed to reach the chamber after propellant valve actuation were 0.7 and 1.5 sec, respectively, at the nominal combustor operating condition. The seed flow lag time (1.5-sec) was intentionally long to prevent admittance of seed into the MHD channel prior to increasing channel wall temperature, thereby preventing electrically conducting seed residue from forming on the cold walls of the channel.

The variations in chamber pressure and in RP-1, oxygen, and seed flow rates are presented in Fig. 24 for a typical firing. Seed flow was stopped approximately 3 sec prior to engine shutdown to ensure removal of all seed residue from the channel walls.

The average values of chamber pressure and oxygen, RP-1, and seed flow rate during the 1-sec period prior to seed flow shutoff (t_2 in Fig. 24) are presented in Table III for all firings. All firings except 15, 25, and 26 were accomplished at a nominal chamber pressure and oxygen-to-fuel ratio of 46 psia and 2.8, respectively. Time t_1 in Fig. 24 and in Table III represents the time from activation of firing circuit to the initiation of chamber pressure increase. Since the time base for all data tabulated in this report is referenced from firing circuit energization, t_1 can be used for correlating events from motor ignition.

The variation in chamber pressure with total propellant flow rate (RP-1, oxygen, and alcohol) is presented in Fig. 25. Chamber pressure varied linearly with total propellant flow rate for flows ranging from 1.13 to 2.00 lb_m/sec and with variations in oxygen-to-fuel ratio ranging from 2.56 to 3.13. Characteristic velocity (c*) ranged from 5125 to 5260 ft/sec. No significant variation or trend in c* with total weight flow or oxygen-to-fuel ratio was apparent over the range tested.

The combustion efficiency based on the theoretical performance of kerosene and oxygen propellants is estimated to be 92 percent, which would provide a combustion chamber gas temperature of approximately 5000°F.

4.2 GENERATOR PERFORMANCE DATA

The measured value of individual channel resistance loads for the ten load bank configurations used is presented in Table IV. Configurations 1 through 5 were used during 45-deg channel testing and 8 through 12 during Hall channel testing. Power dissipating resistors were connected between each active element on the 45-deg channel. During Hall channel testing, power was primarily extracted through one large center resistor connected between the parallel eight electrodes at the upstream and downstream end of the channel. The center 45 elements on the Hall channel were not connected to the load bank.

The physical location of all channel and diffuser pressure and temperature sensing elements is presented in Table V. It should be noted that the pressure and temperature subscript numbering scheme differs for the 45-deg and Hall channel configurations.

The average values of channel pressure during the 1-sec period prior to seed flow shutoff are shown in Table VI. No entry in the pressure level columns indicates that the pressure taps had become restricted with seed residue as previously discussed in Section III.

The channel electrical currents and voltages measured during the 1-sec period prior to seed flow shutoff are presented in Tables VII (45 deg) and VIII (Hall). Channel total current, total voltage, and combustor chamber pressure variation at 1-sec intervals are shown in Fig. 26 for a typical generating run. Sign conventions utilized were: (1) current flowing from channel to load bank denoted positive, (2) current flowing from top channel element to bottom channel element denoted positive, and (3) increasing electrical potential above ground (upstream channel potential) denoted positive.

Typical variations in 45-deg and Hall channel temperature during firings with and without power generation are shown in Table IX. It should be noted that the least division of the pyrometer gages utilized for recording channel temperature was 20°C.

4.3 CHANNEL STRUCTURAL DURABILITY

The determining factor governing the number of test firings accomplished with a given channel configuration was the channel structural and electrical insulation durability. Initially, it was believed that pitting on the internal surface of the electrodes would be a significant factor. However, no pitting or metal erosion in the internal flow passage was observed. The heat sink characteristics of both channels were adequate for firings having burn durations to 15 sec.

Testing with the 45-deg channel was discontinued after a total of 34 firings with a total burn duration of 272 sec because flame was observed emanating from between elements of the upstream transition section. Post-fire photographs of the 45-deg channel are shown in Fig. 27. The opening in the upstream transition section through which flame was observed emanating is shown in Fig. 27b. An epoxy resin installed in the crack following firing 26 (192 sec total firing time) was ineffective in providing a permanent seal. Partial blowout of the mica paper insulation from between some channel segments was also observed.

Hall channel testing was discontinued after 18 firings with a total burn duration of 224 sec because of gas leakage at the downstream transition section. A copper plate insulated with mica paper was installed with ceramic-insulated screws to seal the cracks in the transition section vertical walls (Fig. 28a). However, during the subsequent firing, gas leakage through the bottom downstream transition section burned through the Teflon® insulator pad (which insulated the channel from the support stand) (Fig. 28b) causing an electrical short. Testing with the Hall channel was therefore terminated.

APPENDIXES

I. ILLUSTRATIONS

II. TABLES

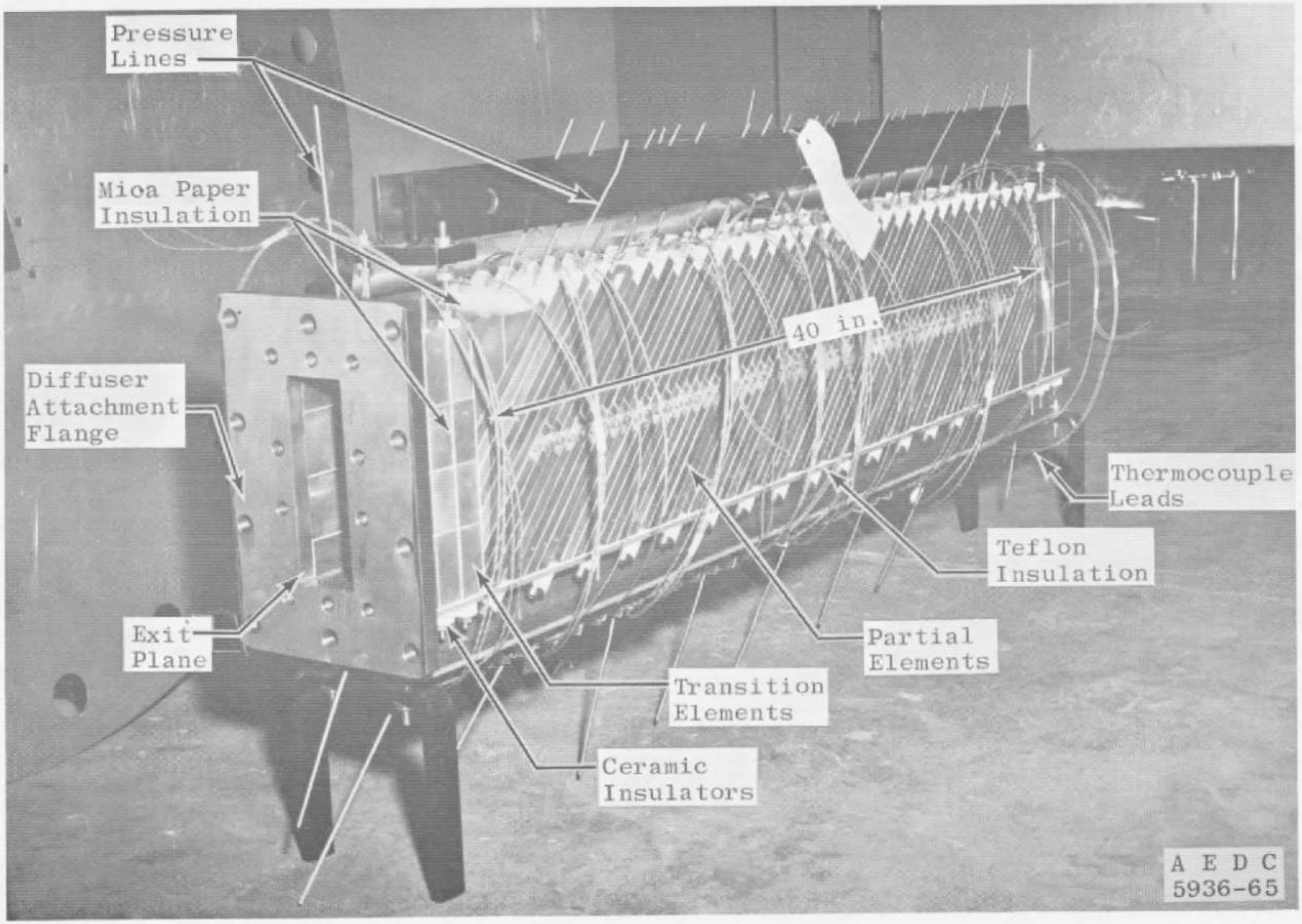


Fig. 1 Photograph of 45-deg Segmented Wall Channel

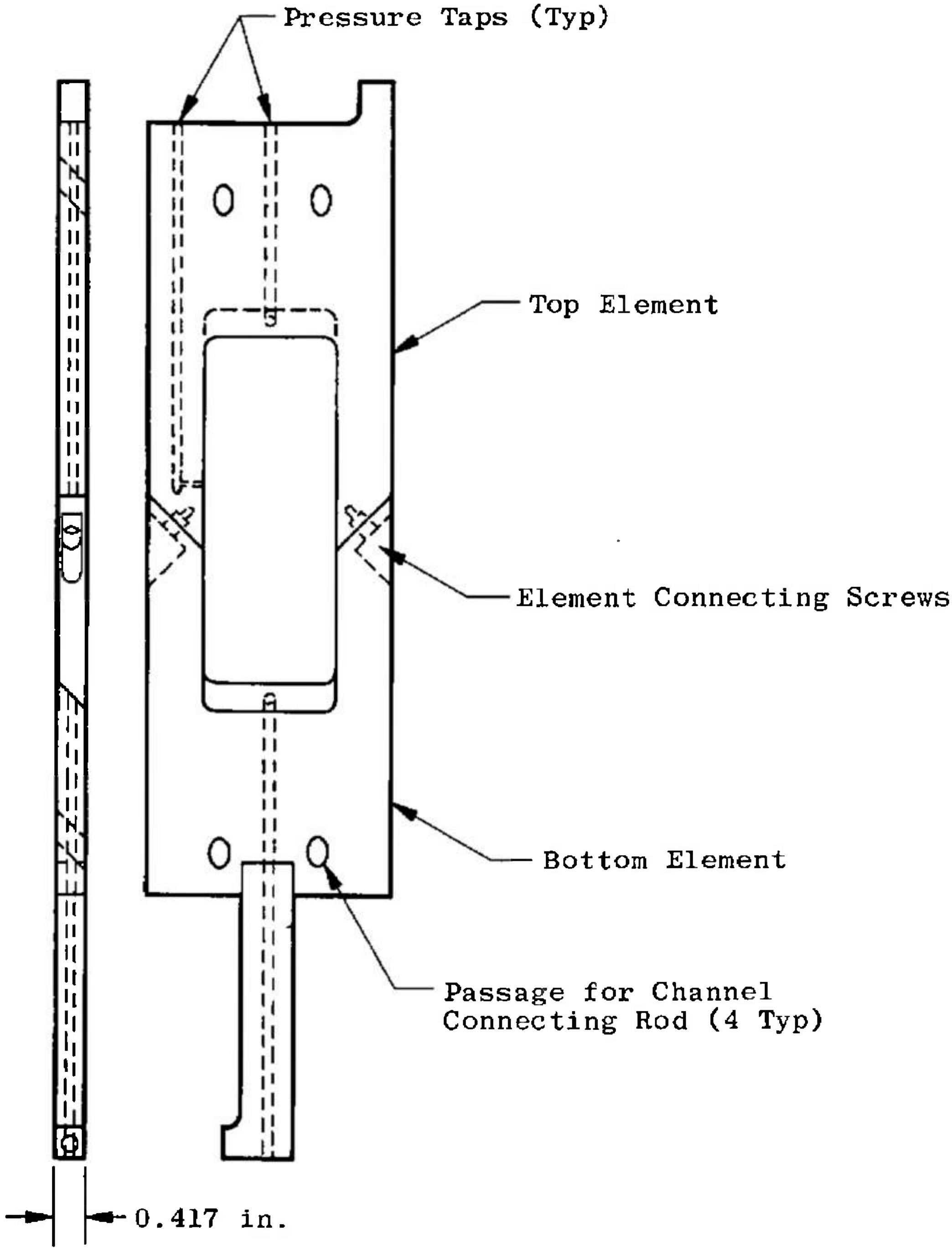


Fig. 2 Schematic of Typical 45-deg Channel Segment

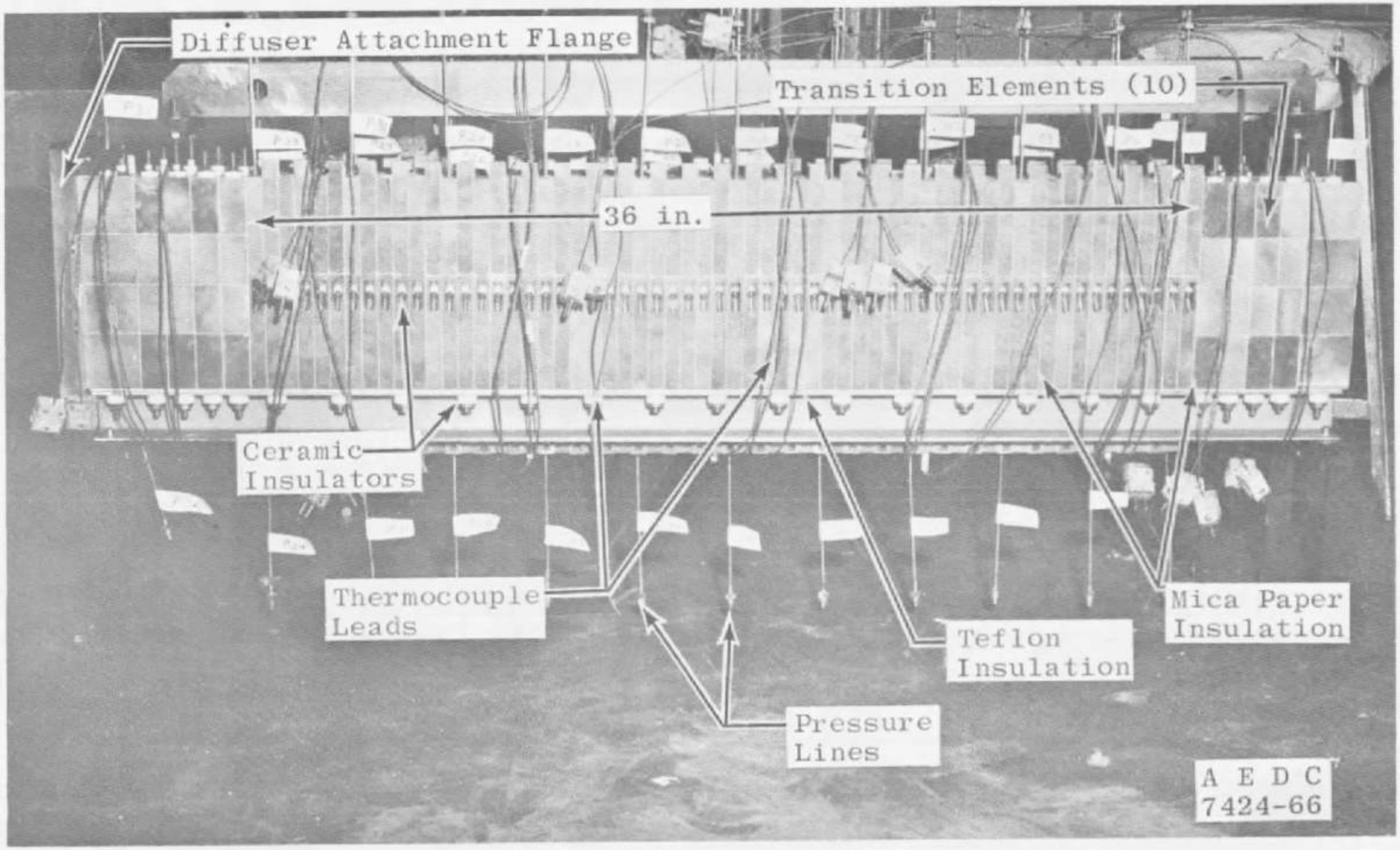


Fig. 3 Photograph of Hall Segmented Wall Channel

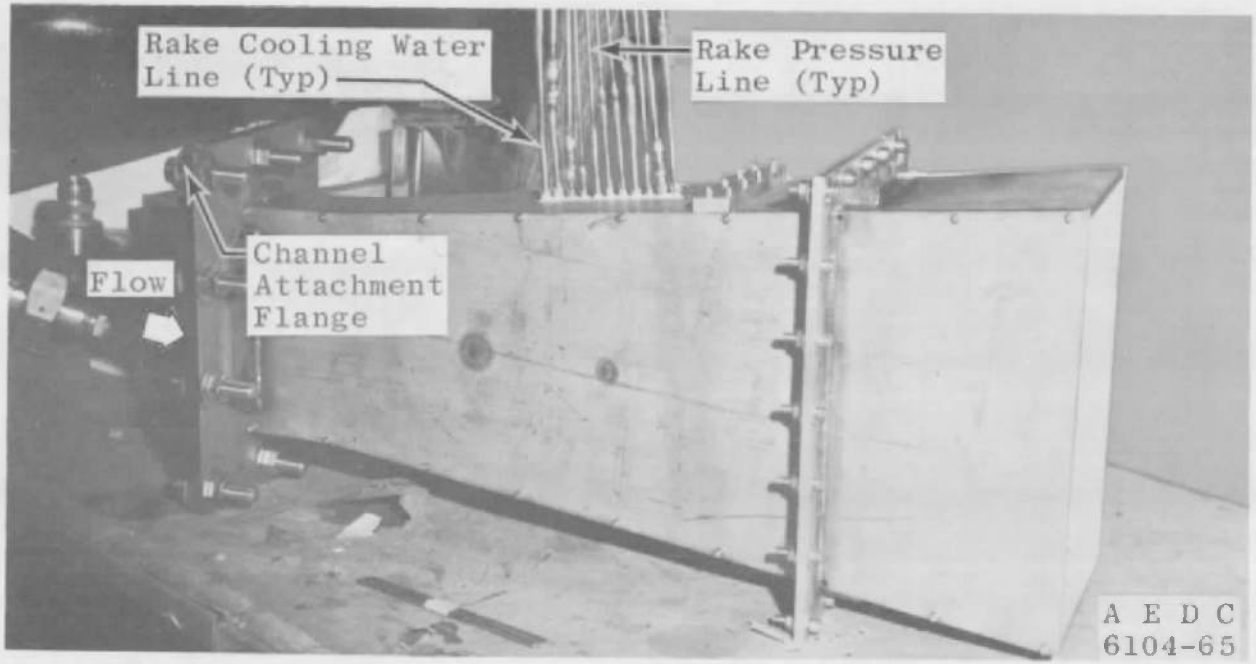


Fig. 4 Photograph of Diffuser

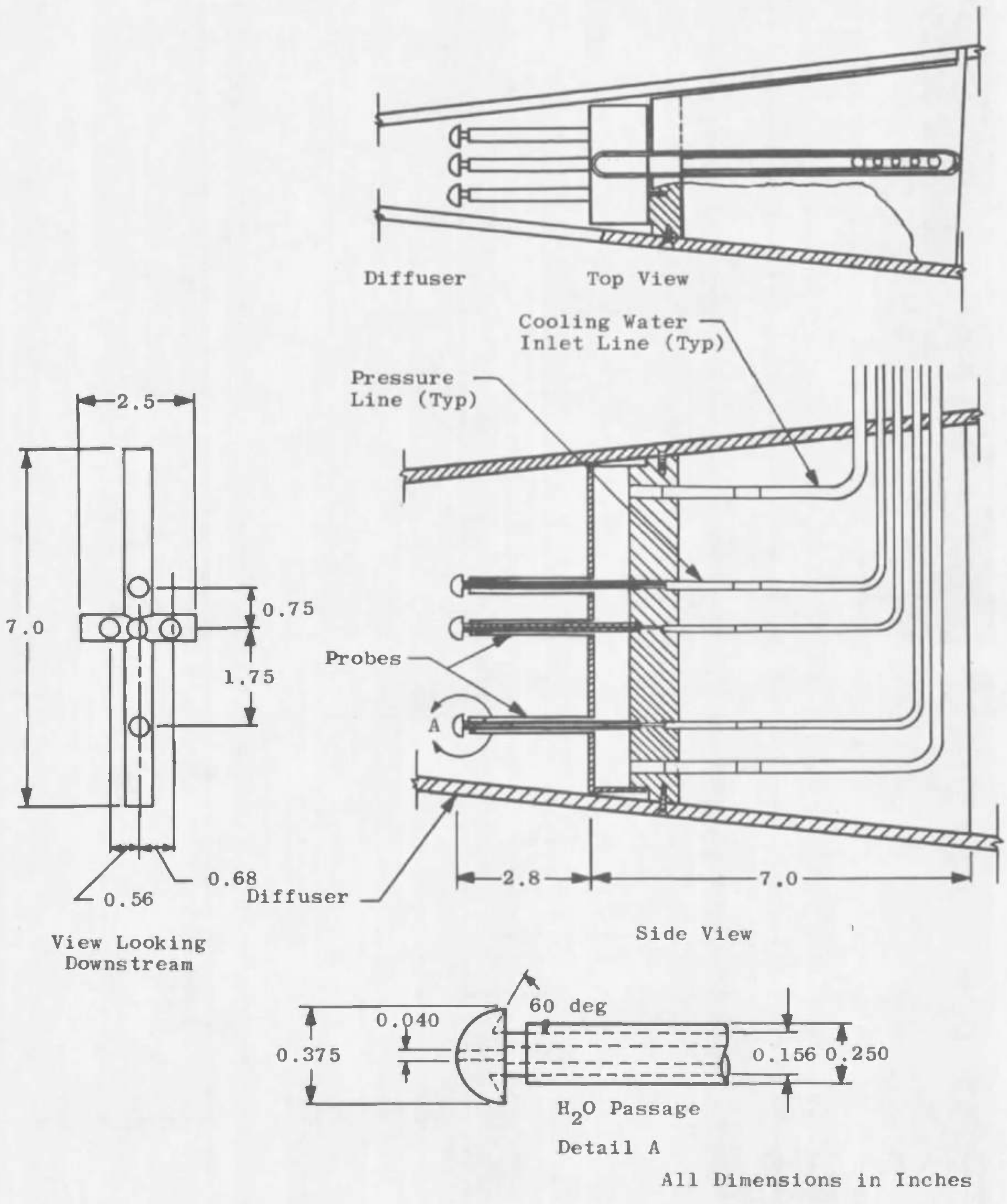
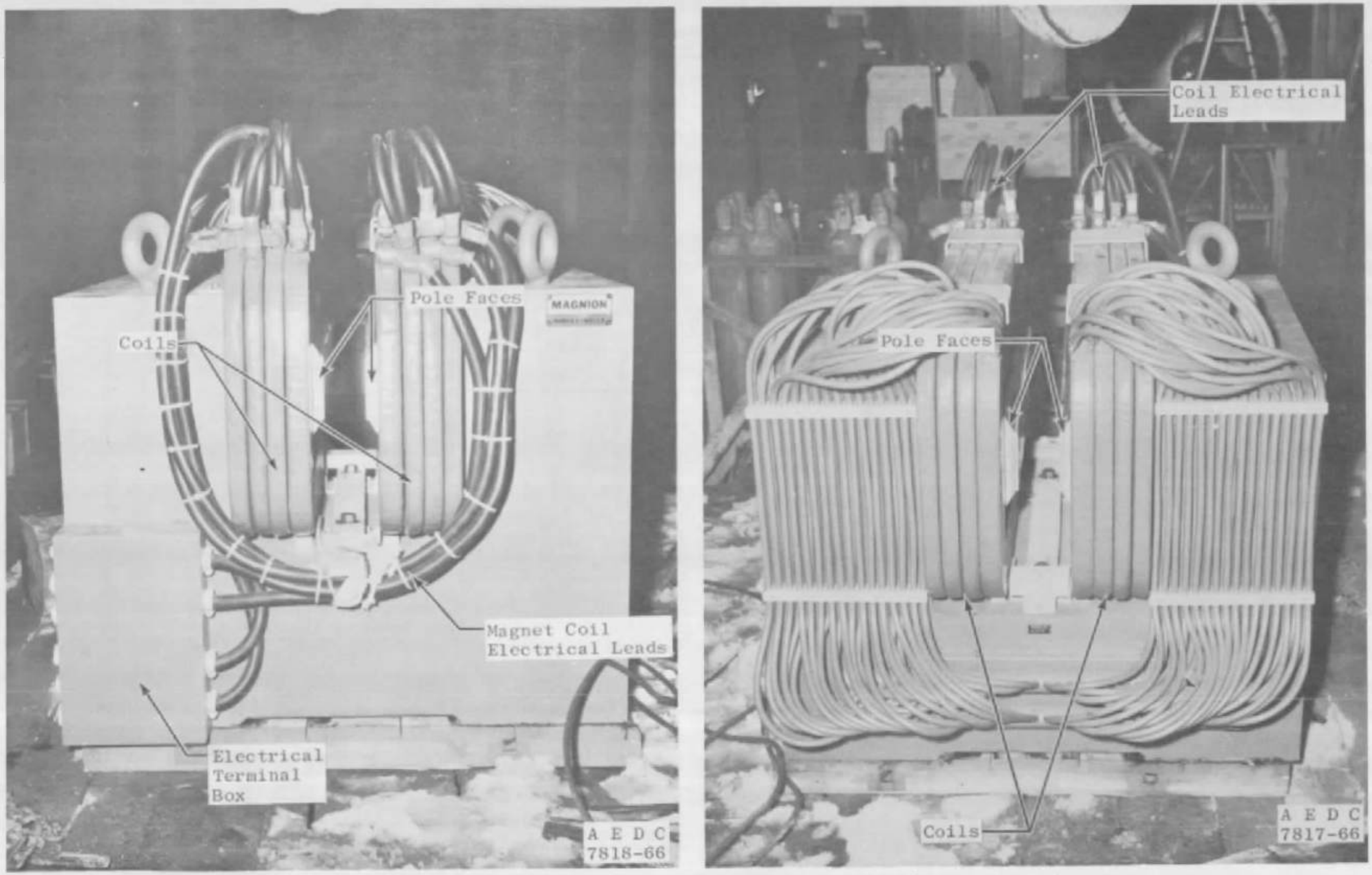


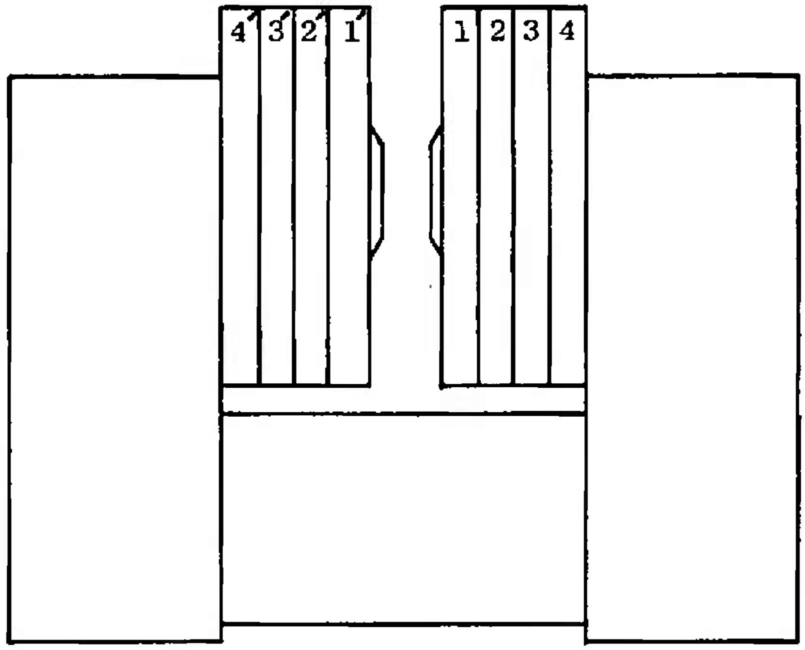
Fig. 5 Schematic of Total Pressure Rake Assembly



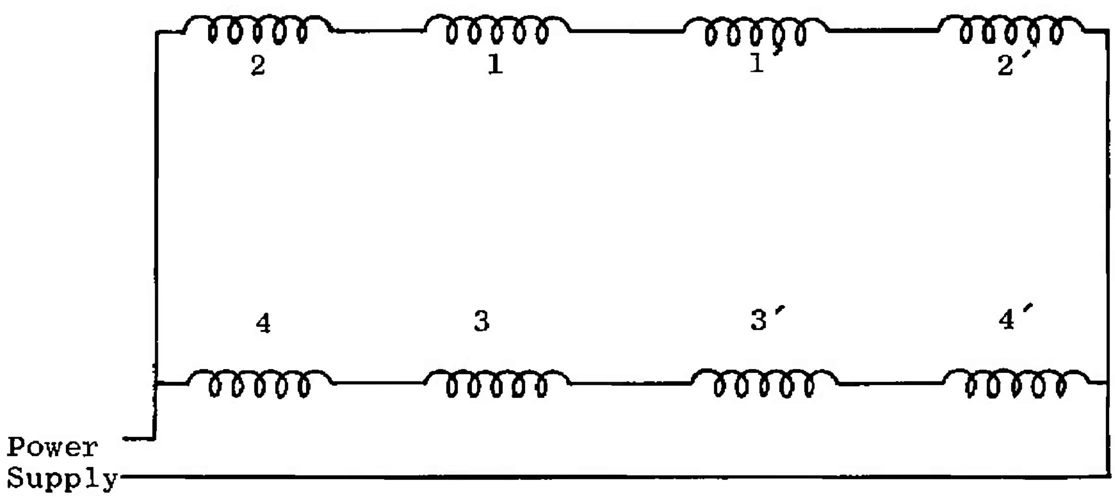
a. Photograph, Looking Upstream

b. Photograph, Looking Downstream

Fig. 6 Electromagnet



Coil Locations
(Looking Upstream)



c. Coil Electrical Schematic

Fig. 6 Concluded

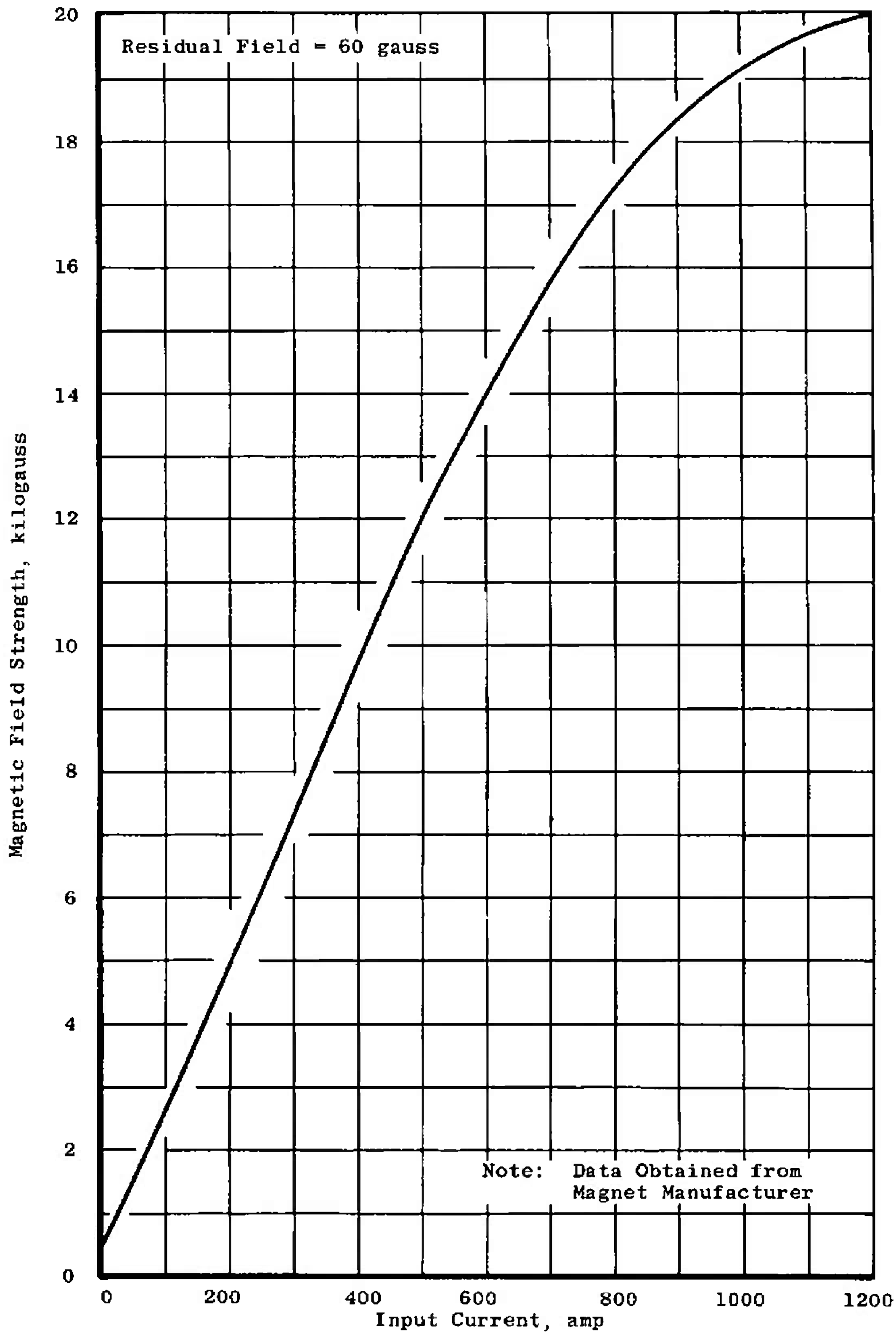


Fig. 7 Magnet Field Strength as a Function of Input Current

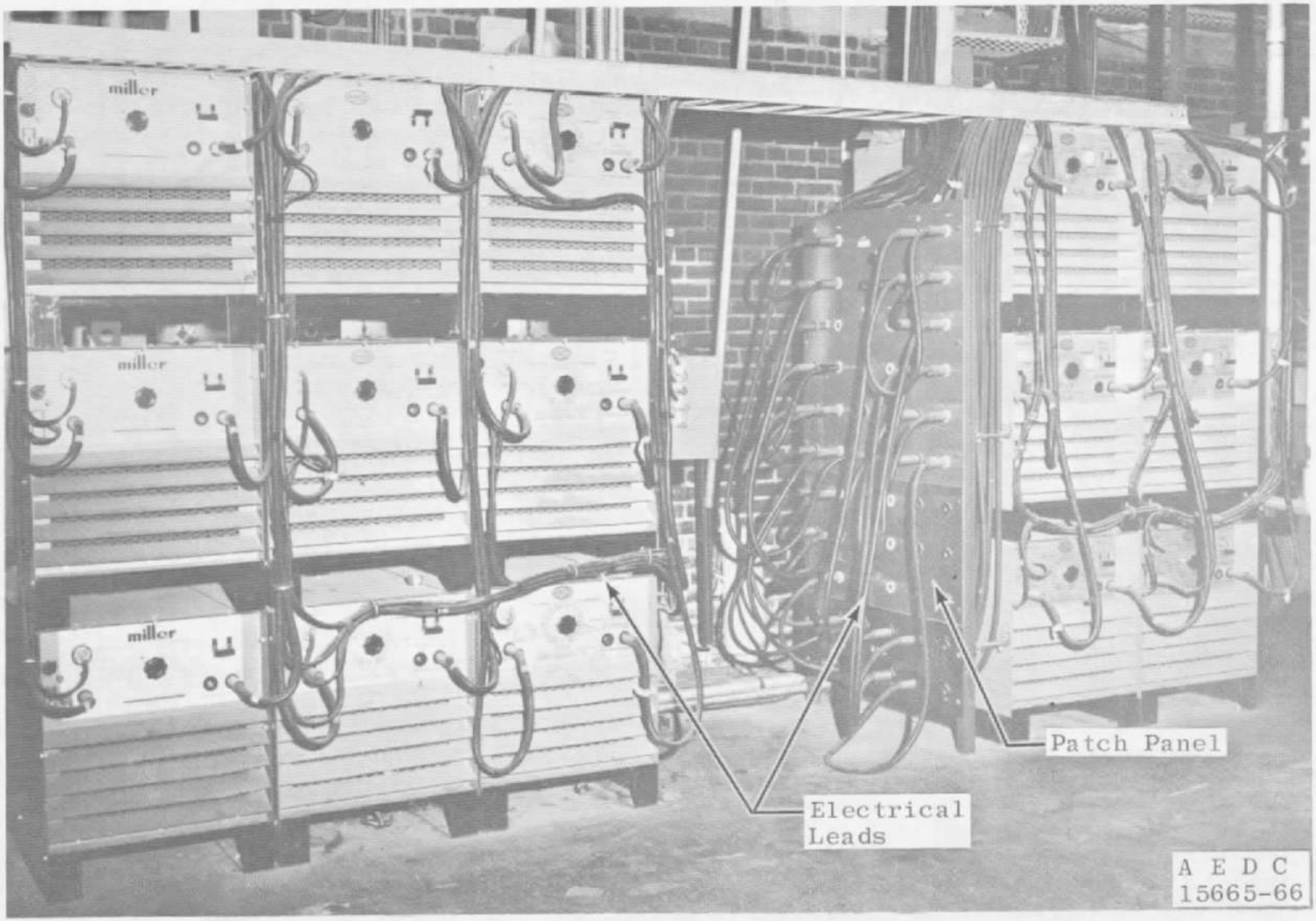
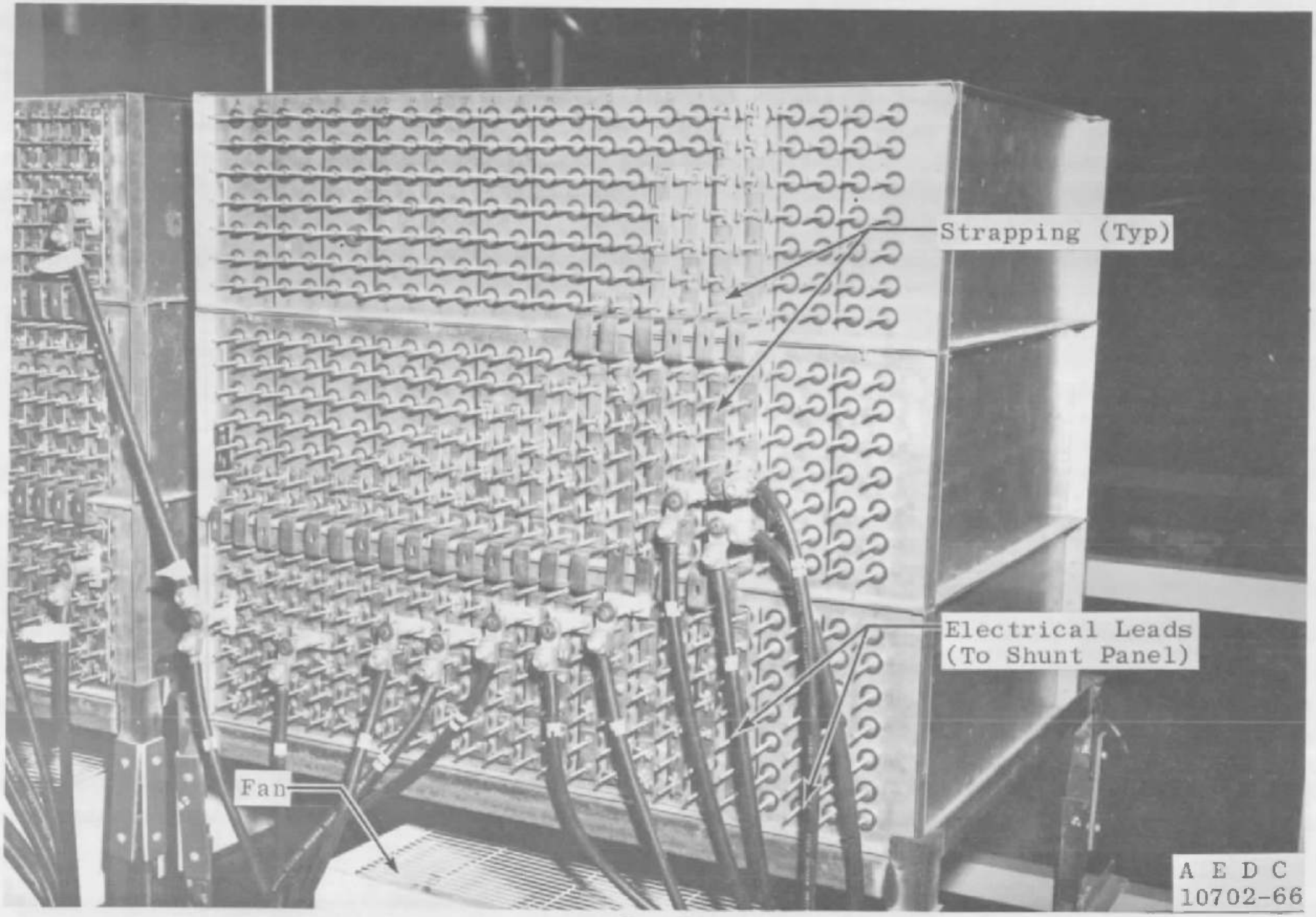
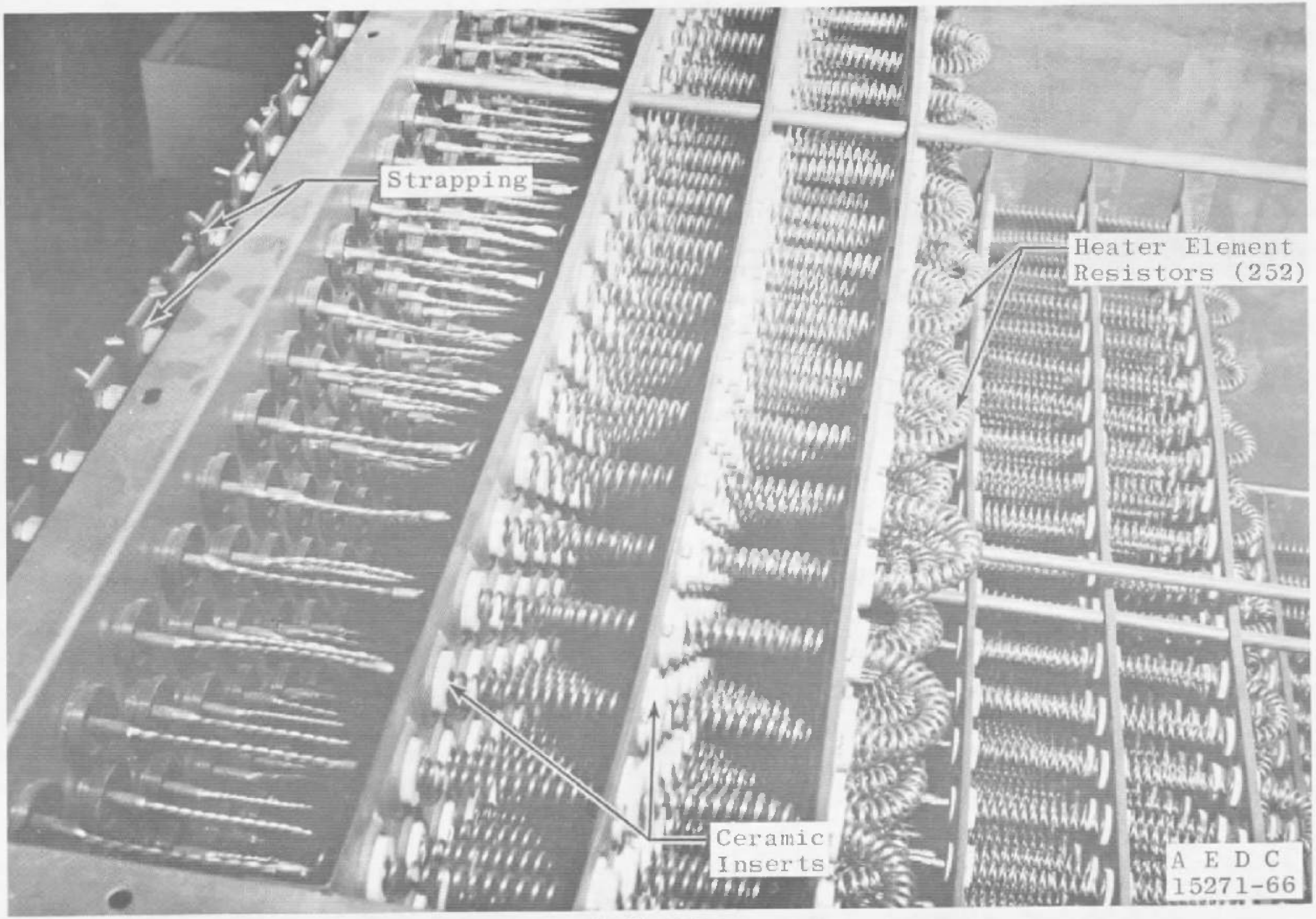


Fig. 8 Photograph of Magnet Input Power Supplies



a. Front View

Fig. 9 Photograph of Typical Load Bank Unit



b. Top View

Fig. 9 Concluded

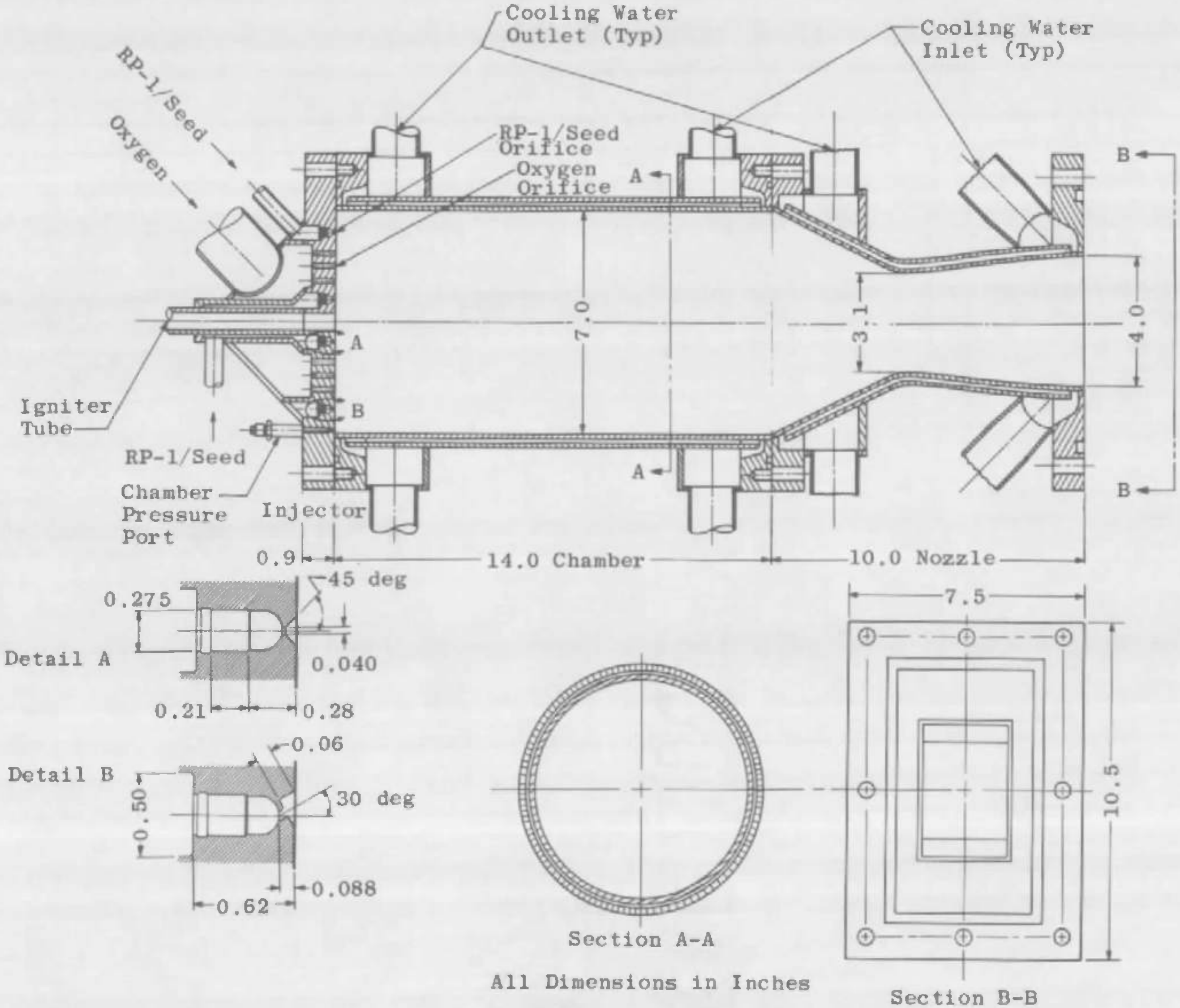


Fig. 10 Schematic of Combustor

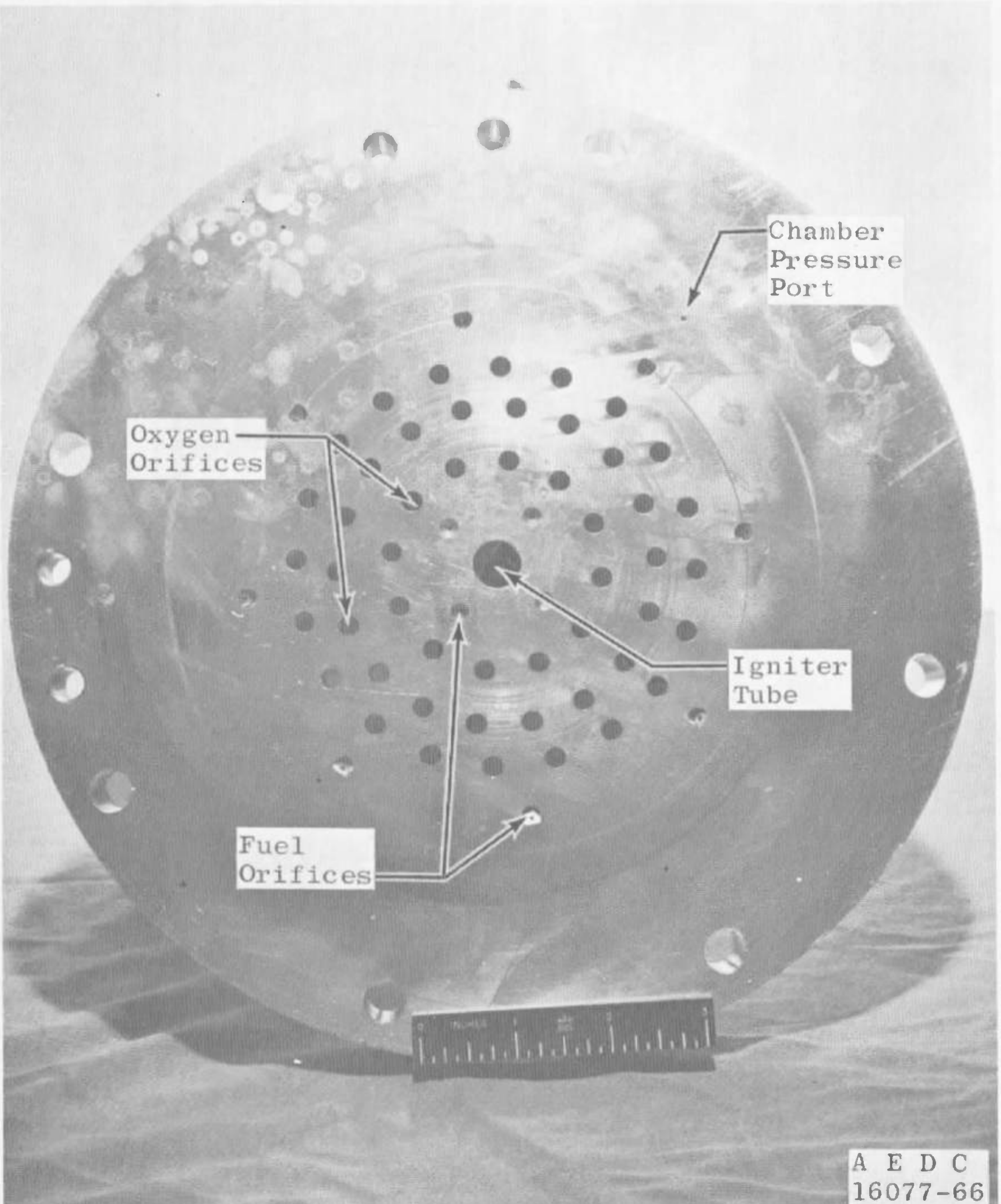
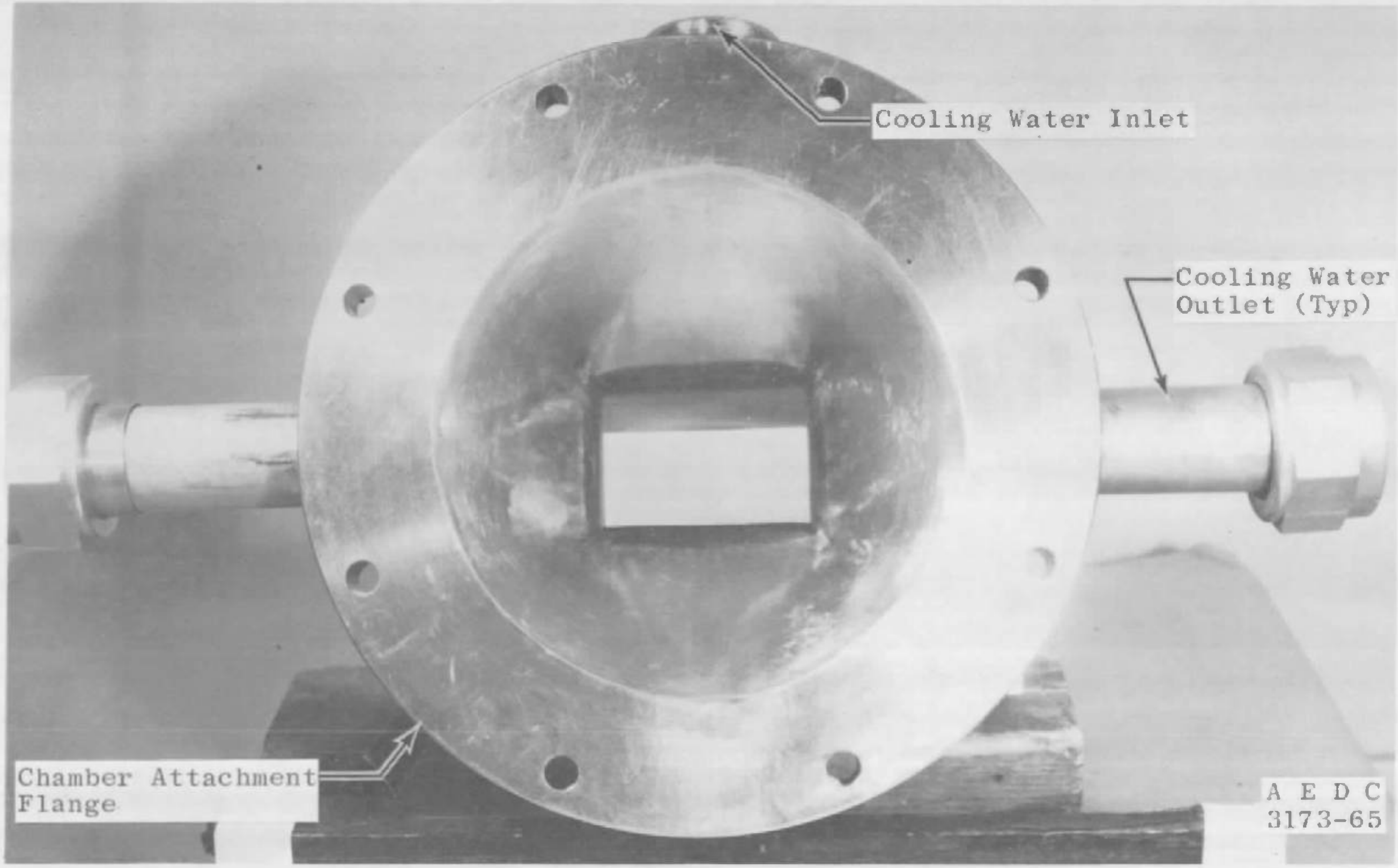
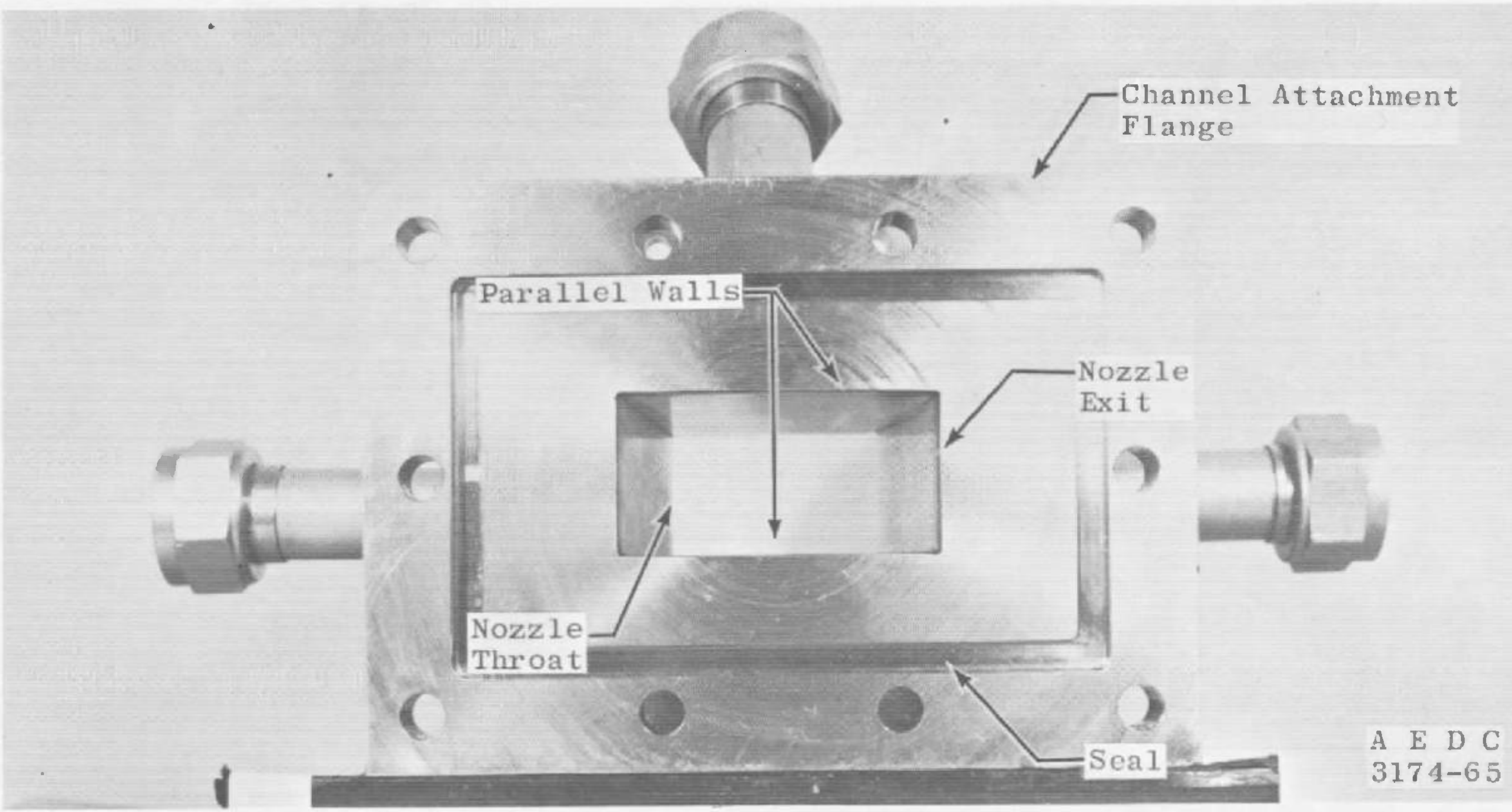


Fig. 11 Photograph of Injector



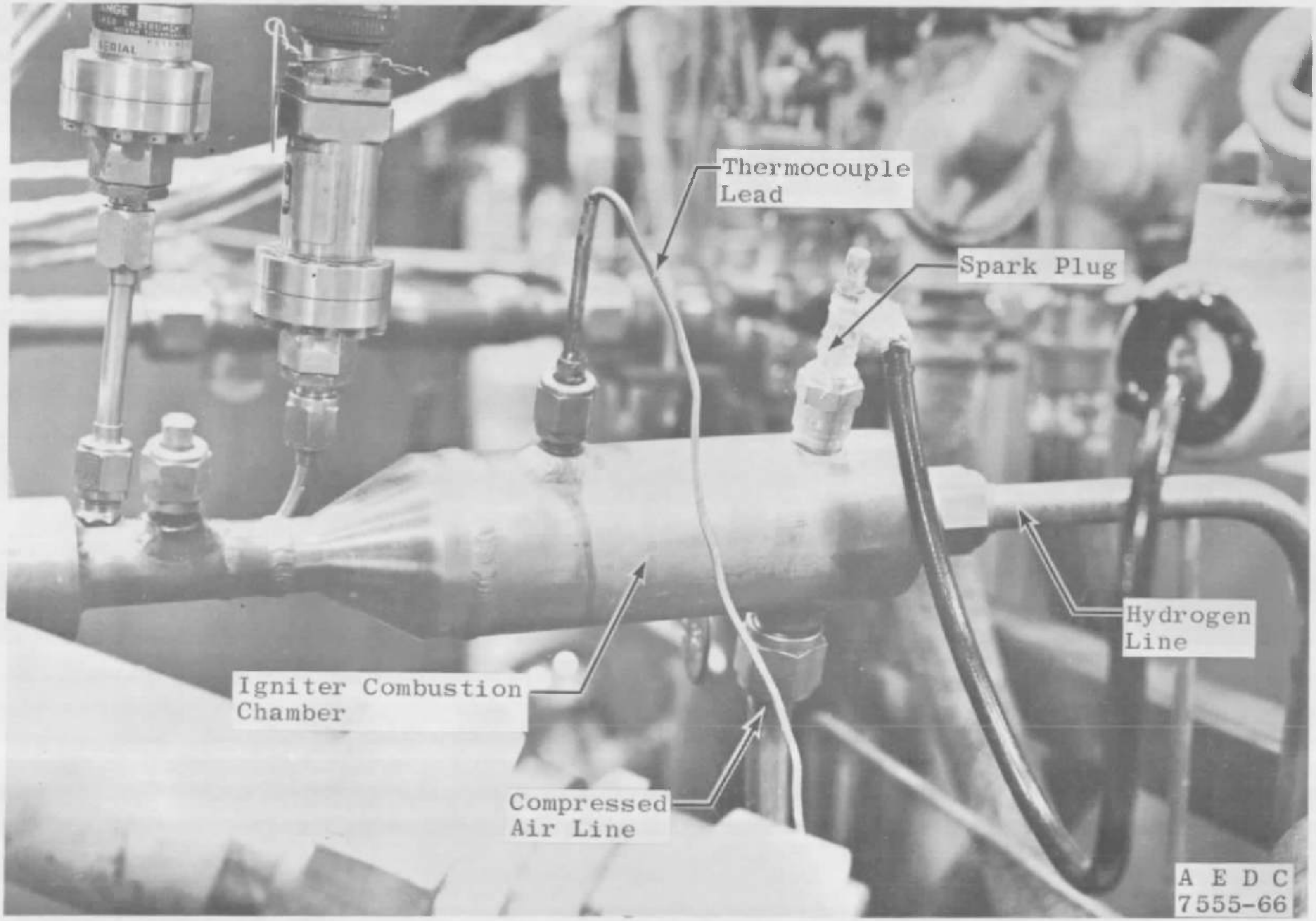
a. Looking Downstream

Fig. 12 Photographs of Water-Cooled Exhaust Nozzle Assembly



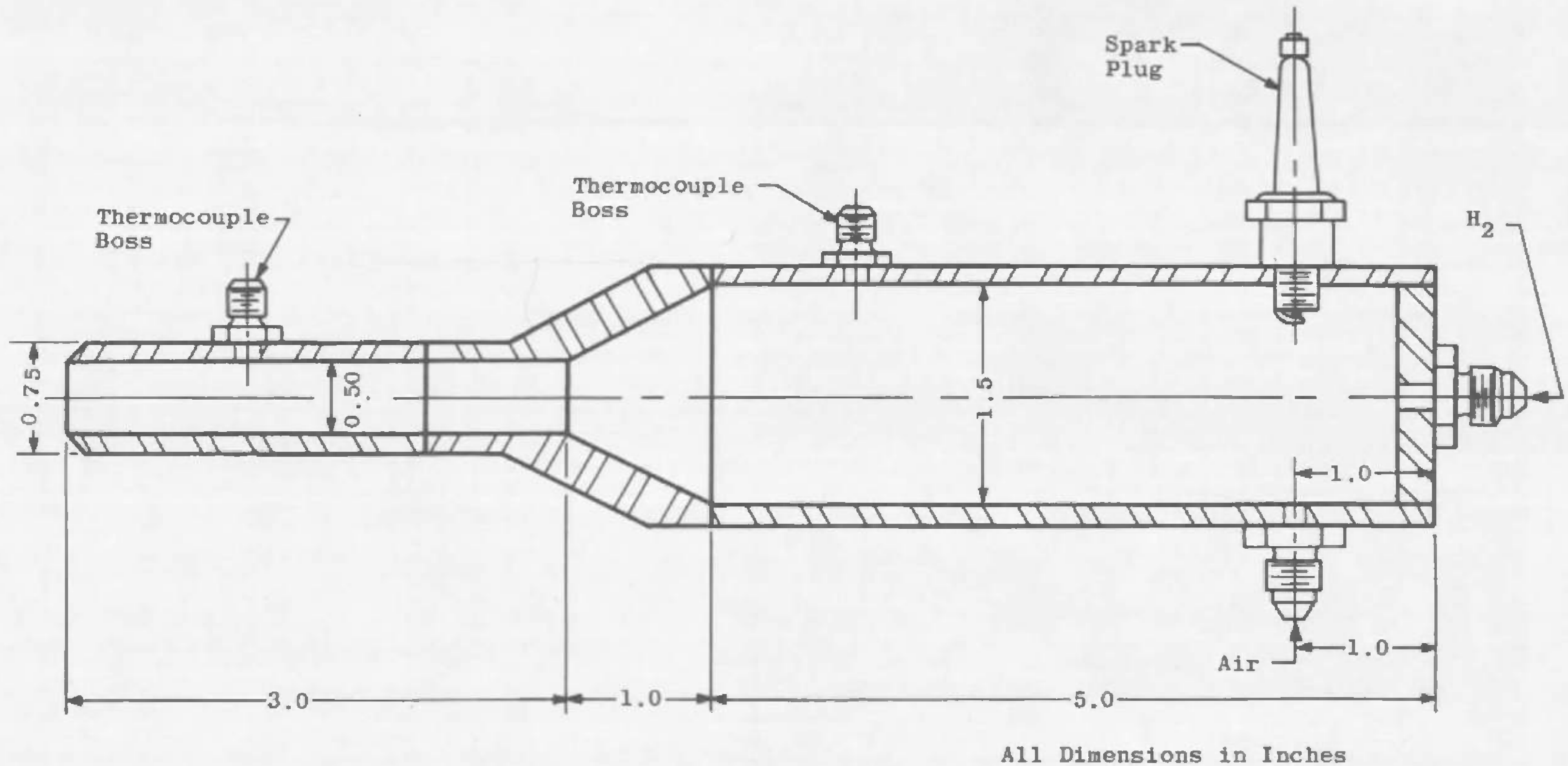
b. Looking Upstream

Fig. 12 Concluded



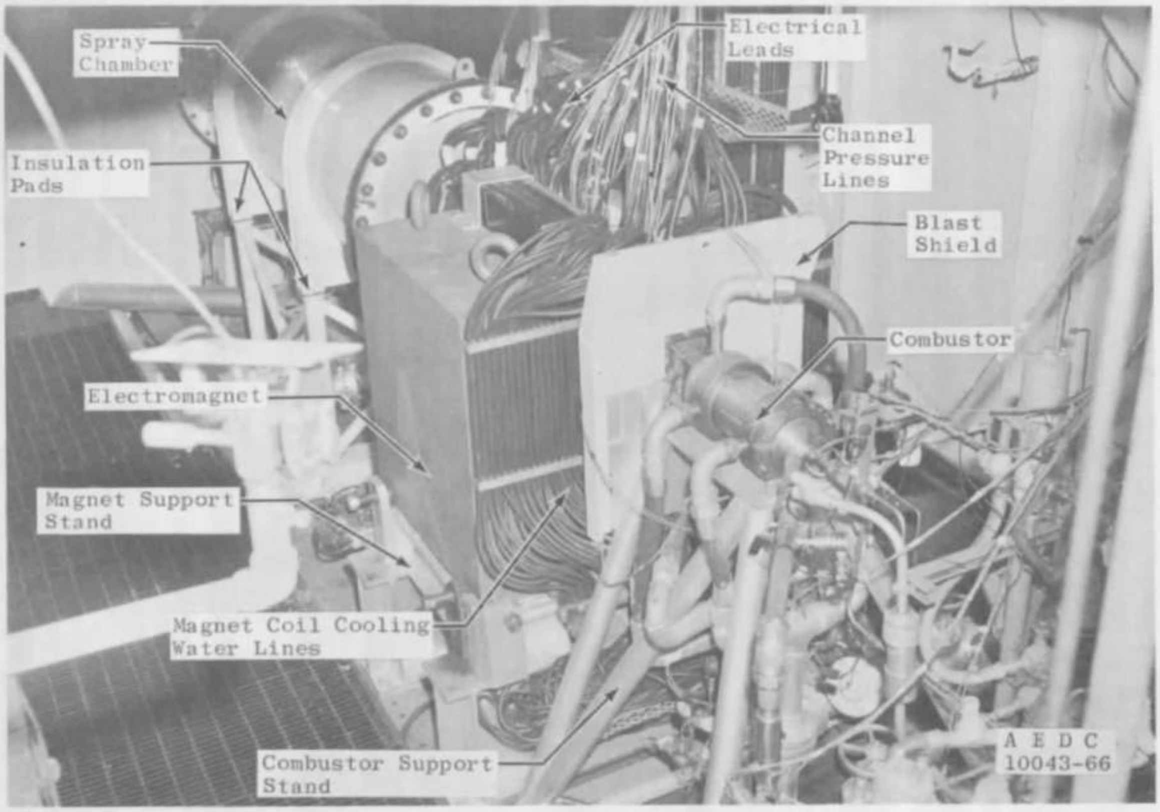
a. Photograph

Fig. 13 Igniter Assembly

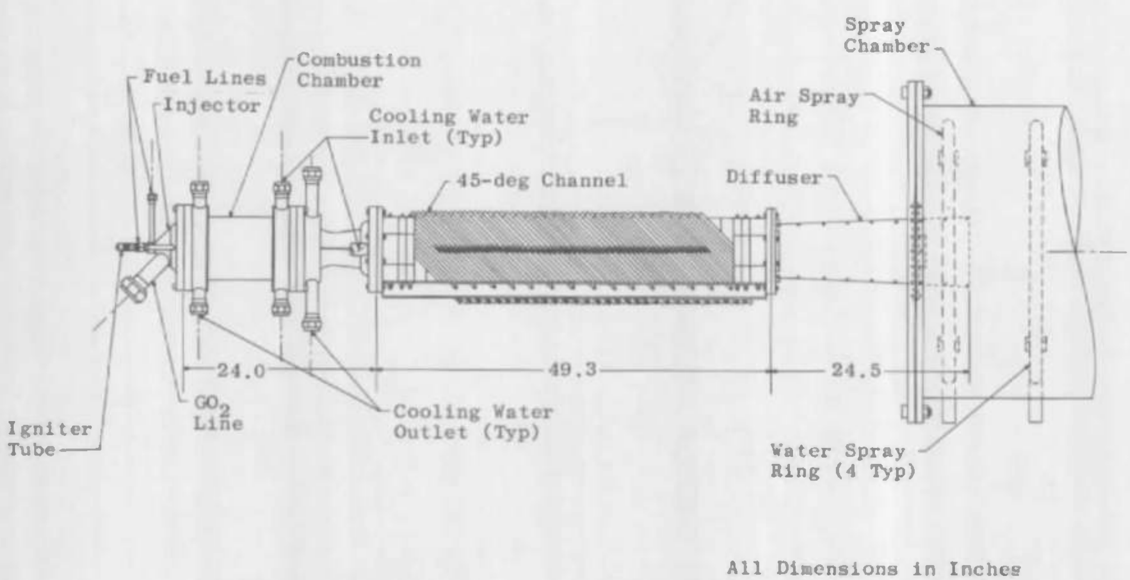


b. Schematic

Fig. 13 Concluded



a. Photograph



b. Schematic

Fig. 14 Installation of MHD Generator Assembly in Propulsion Research Area (R-2C-4)

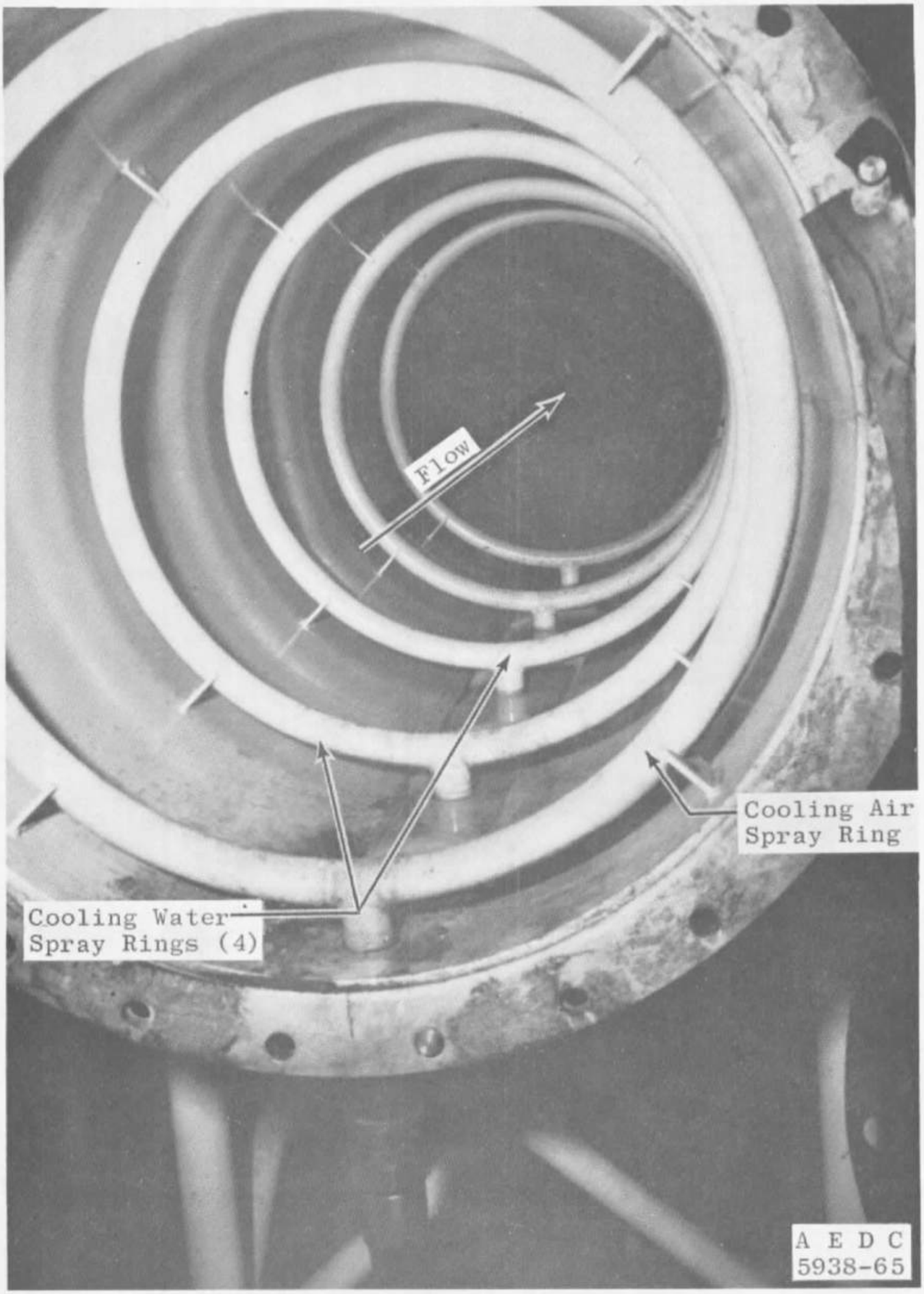
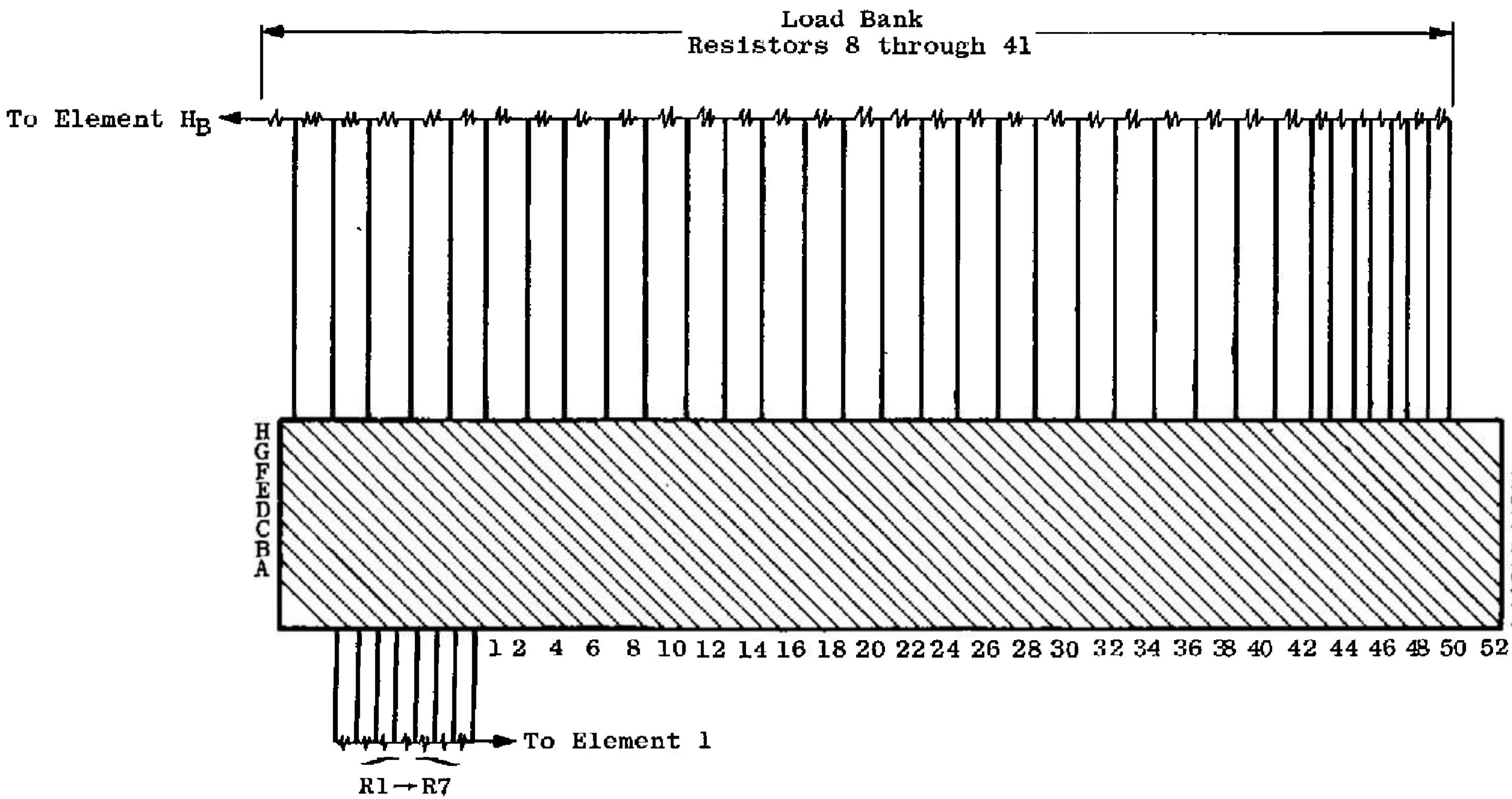
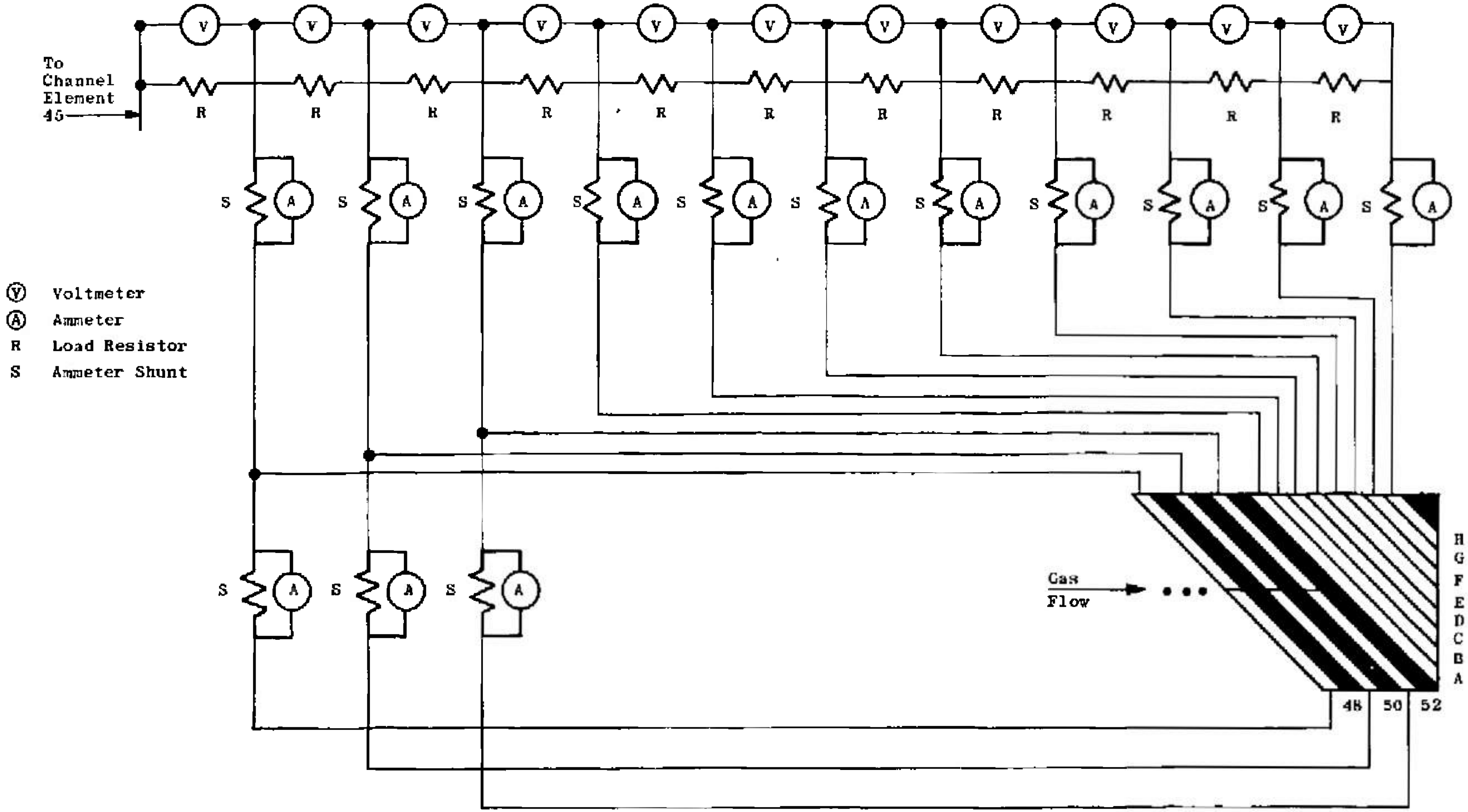


Fig. 15 Photograph of Spray Chomber



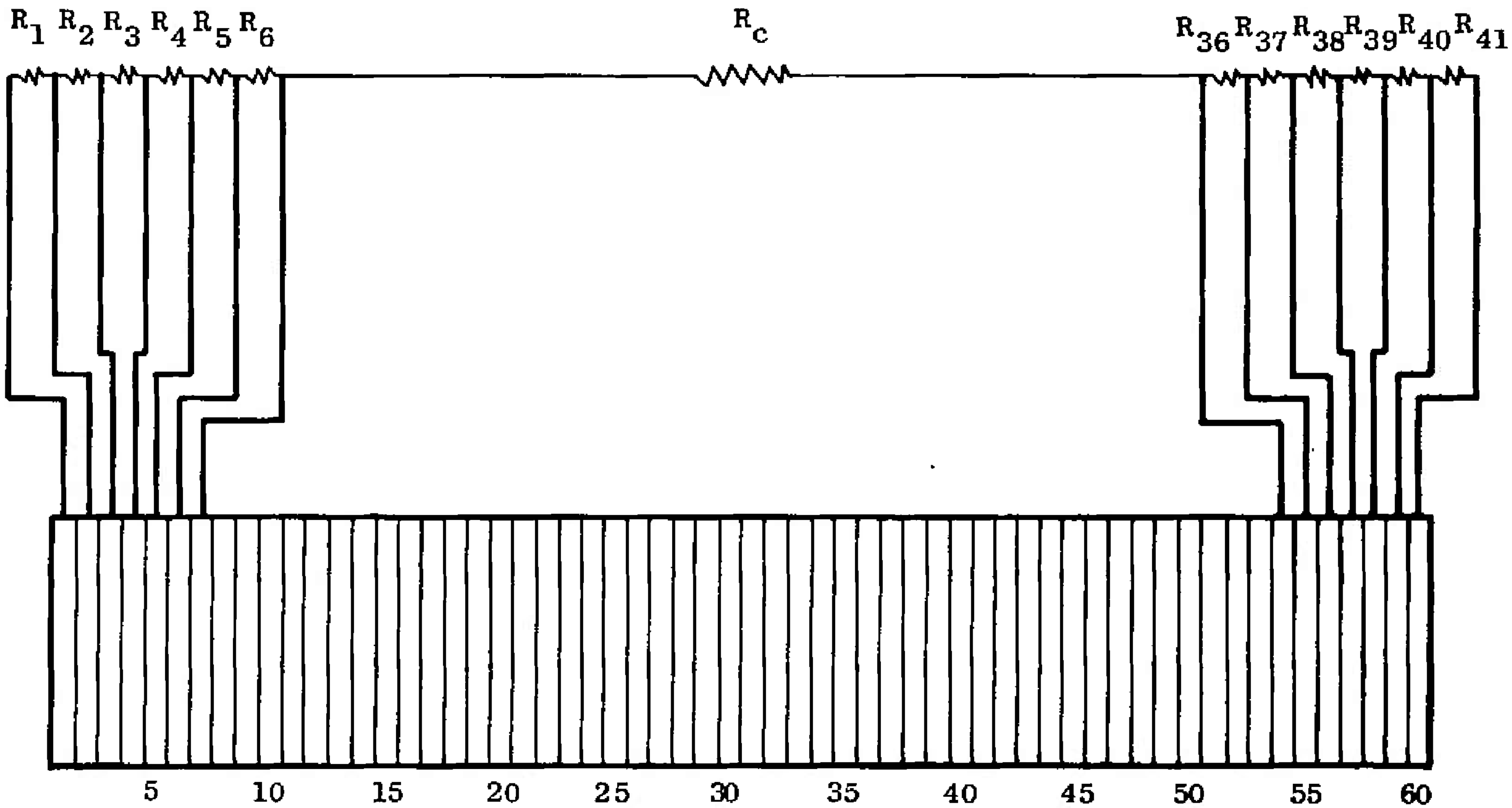
a. Without Instrumentation

Fig. 16 Schematic of Typical Electrical Circuit, 45-deg Channel



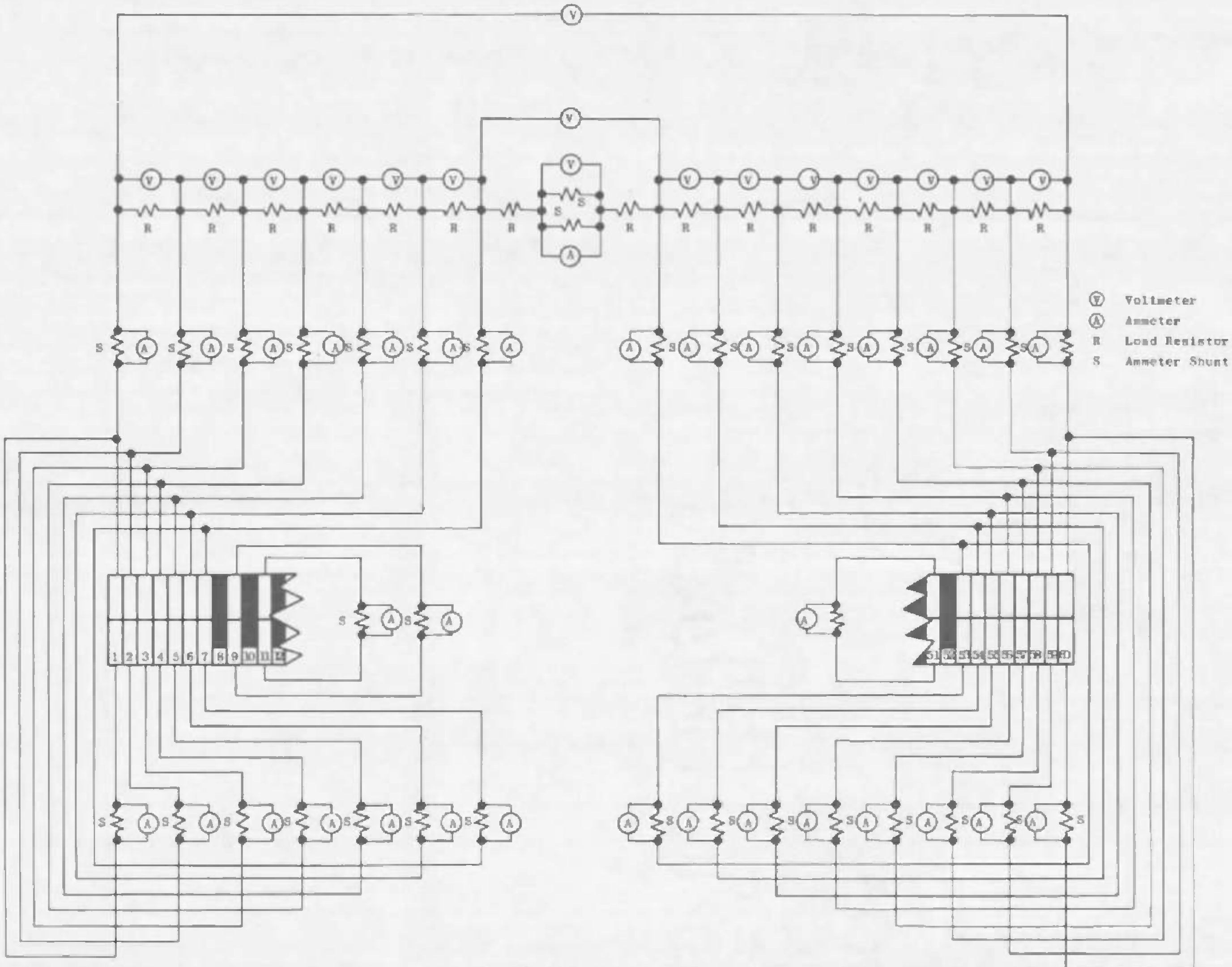
b. With Instrumentation

Fig. 16 Concluded



a. Without Instrumentation

Fig. 17 Schematic of Typical Electrical Circuit, Hall Channel



b. With Instrumentation

Fig. 17 Concluded

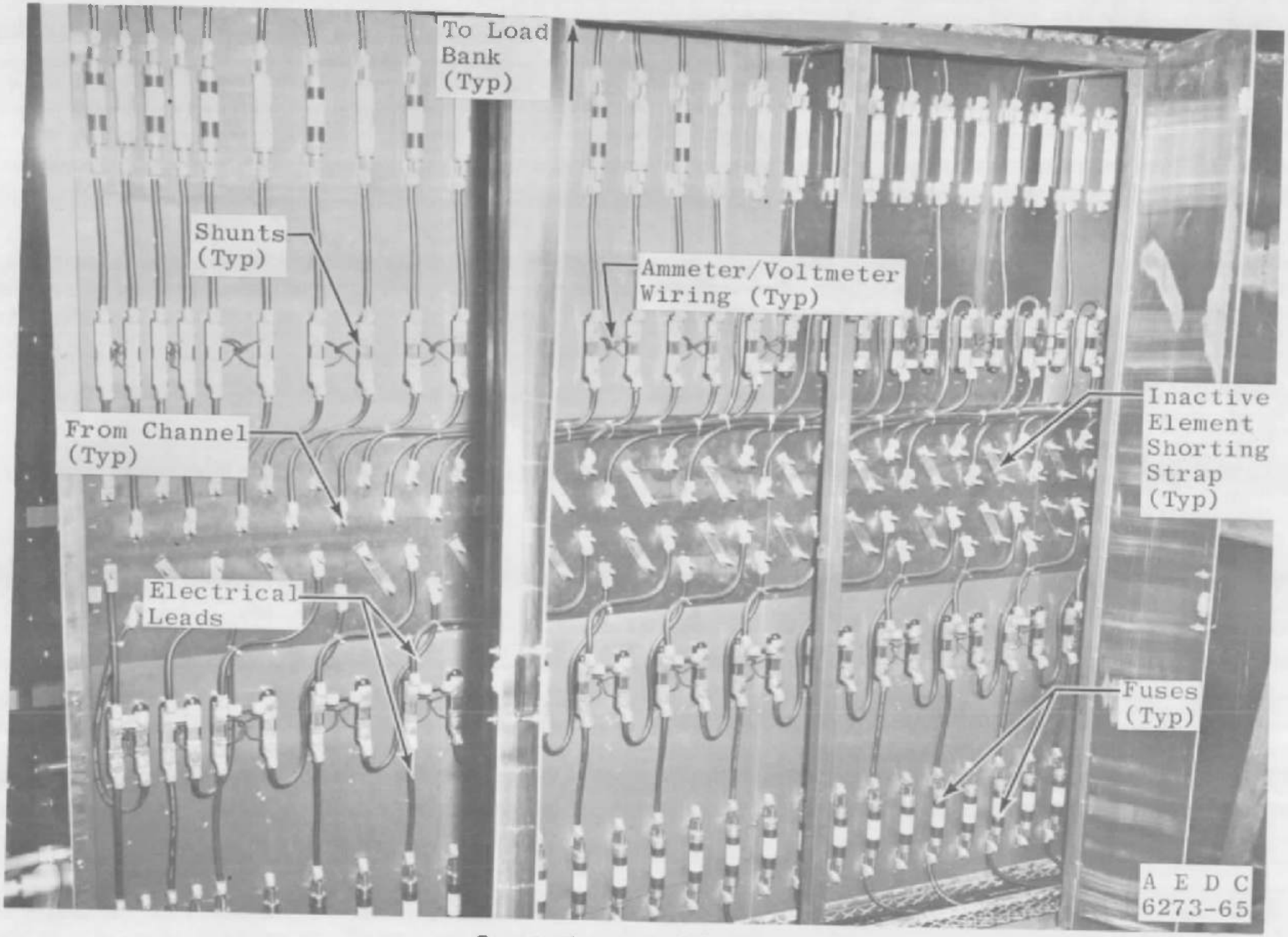


Fig. 18 Photograph of Shunt Panel

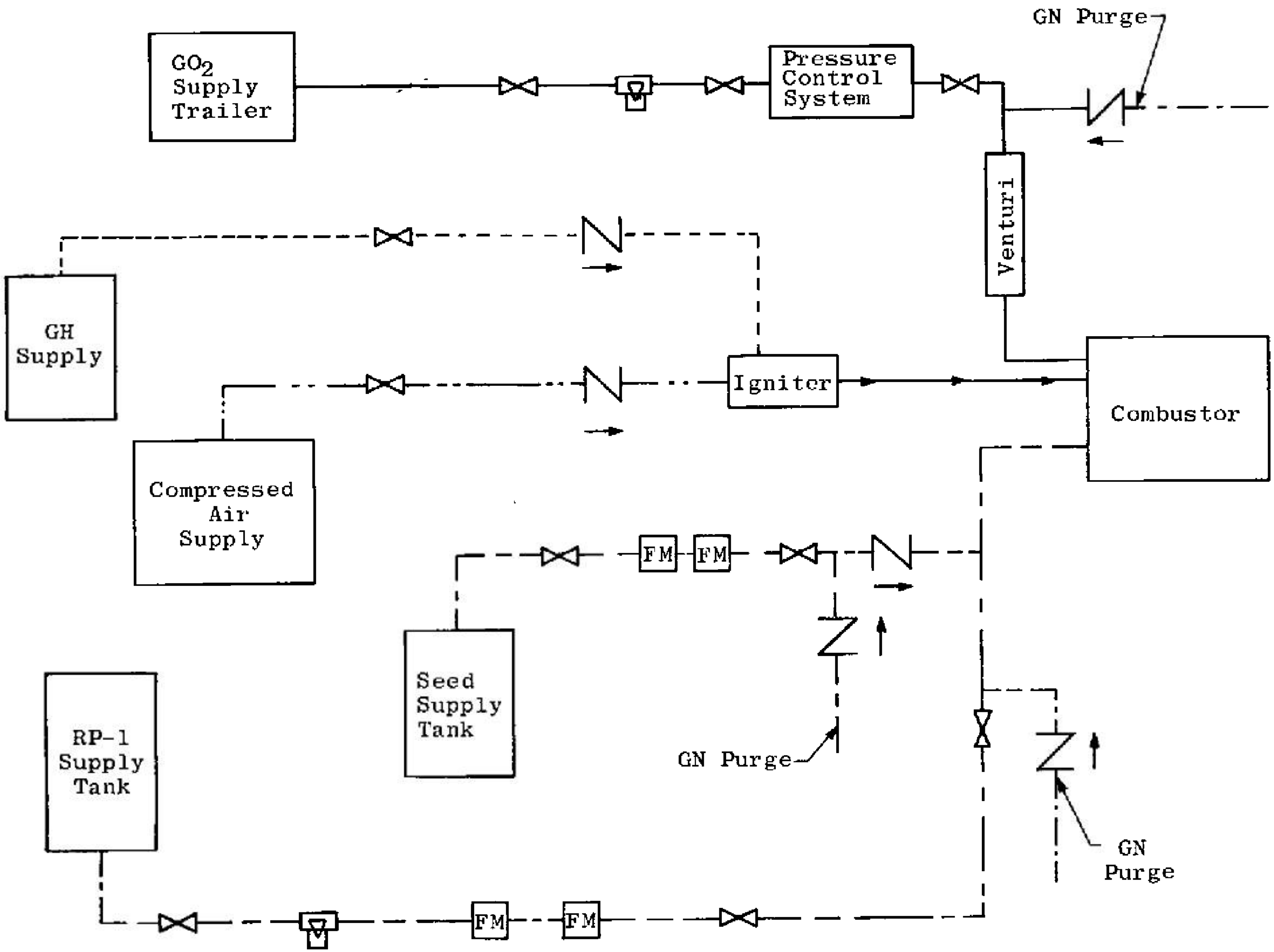
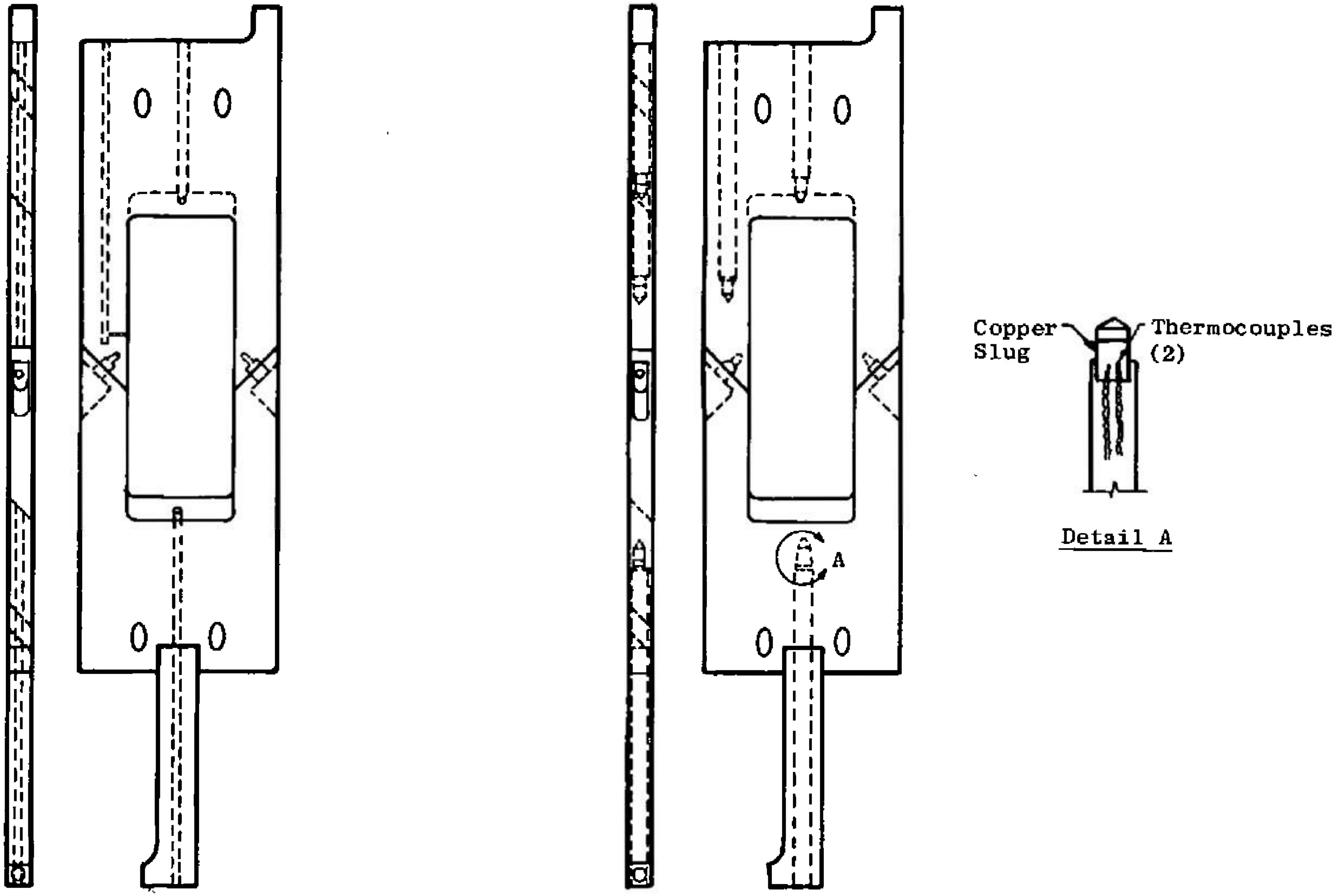


Fig. 19 Schematic of Propellant System



a. Pressure

b. Temperature

Fig. 20 Schematic of Typical Channel Element Pressure and Temperature Instrumentation

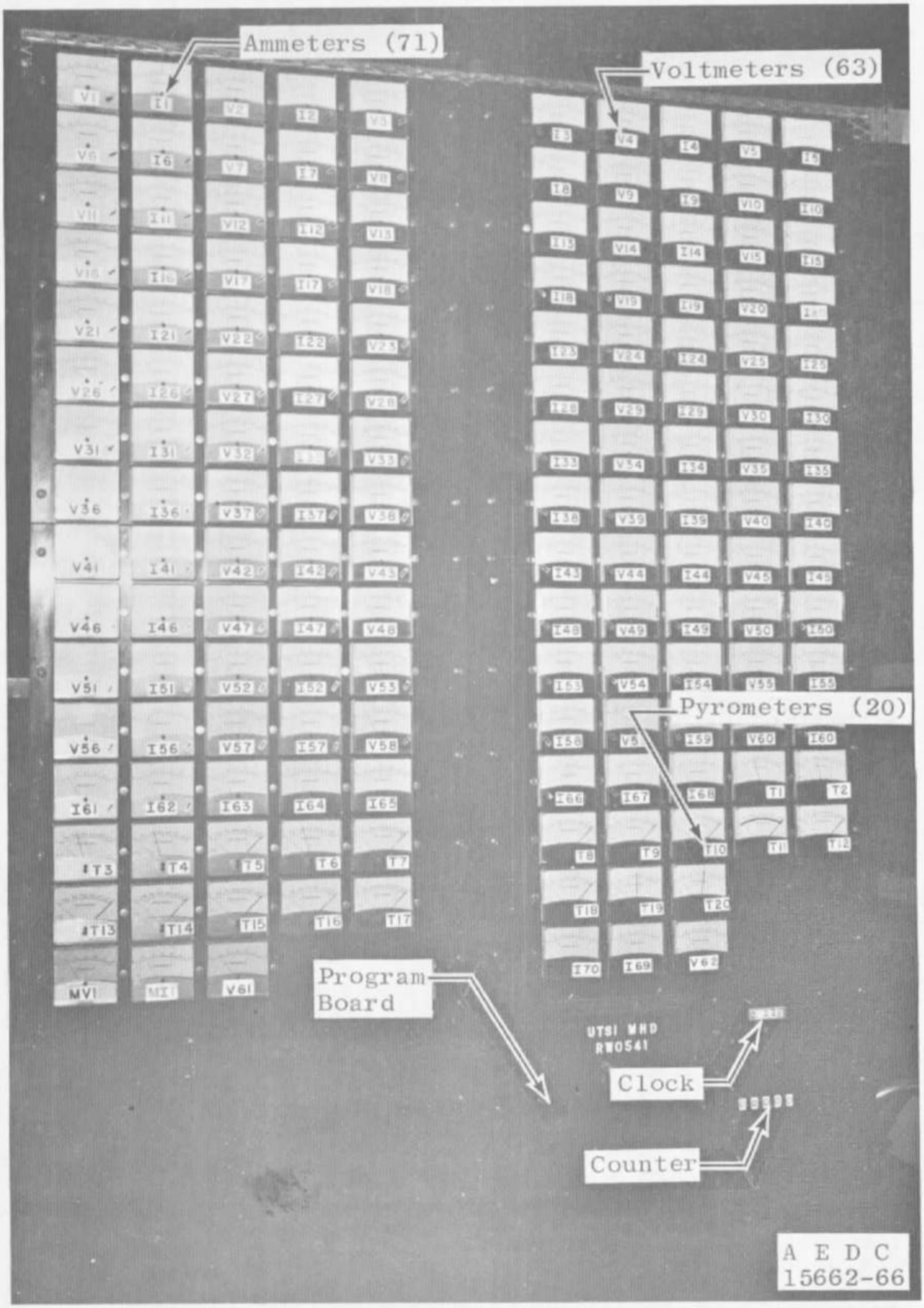


Fig. 21 Photograph of Meter Panel

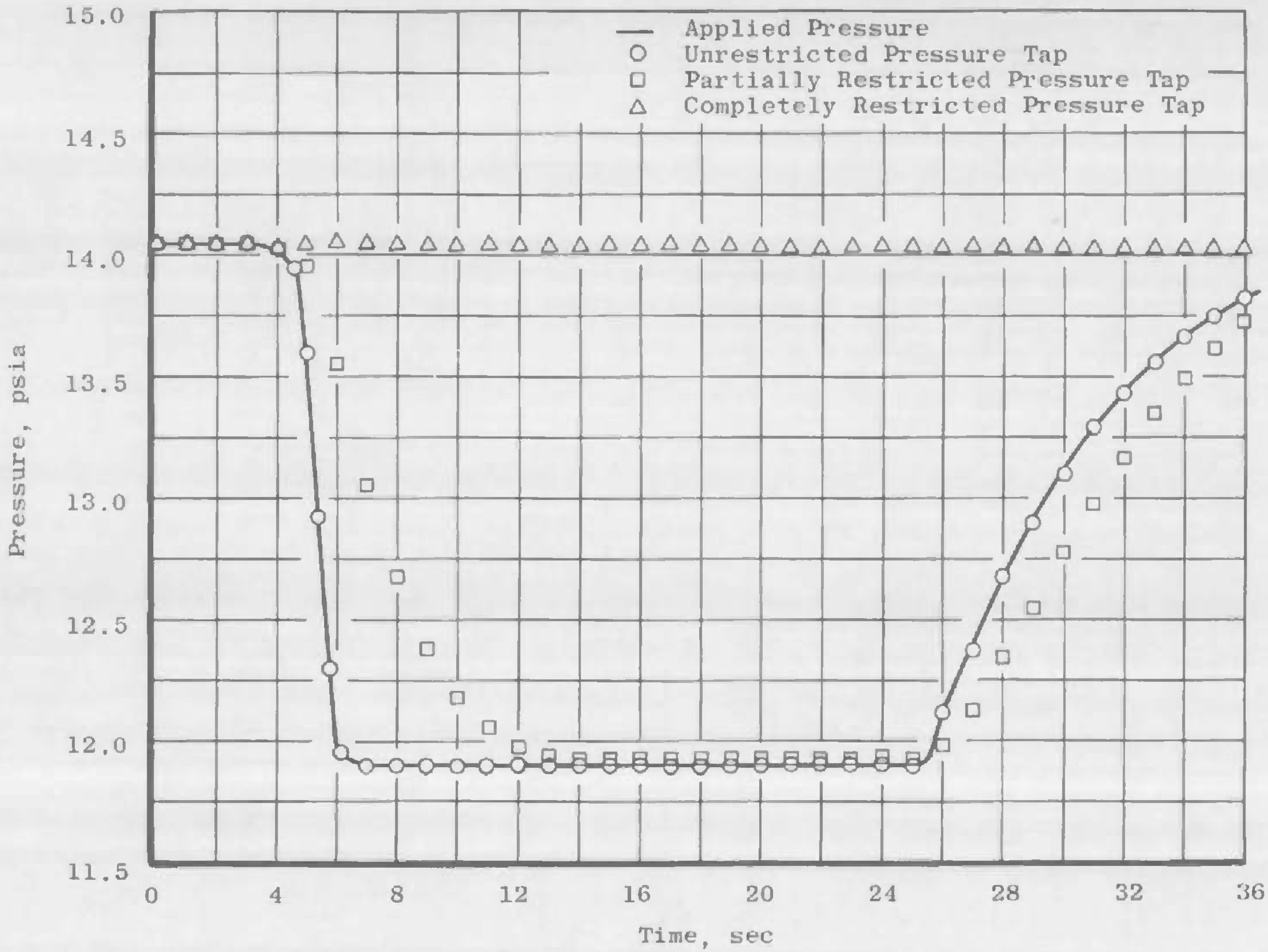


Fig. 22 Comparison of Channel Pressure Responses for Clear, Partially Restricted, and Fully Restricted Pressure Taps

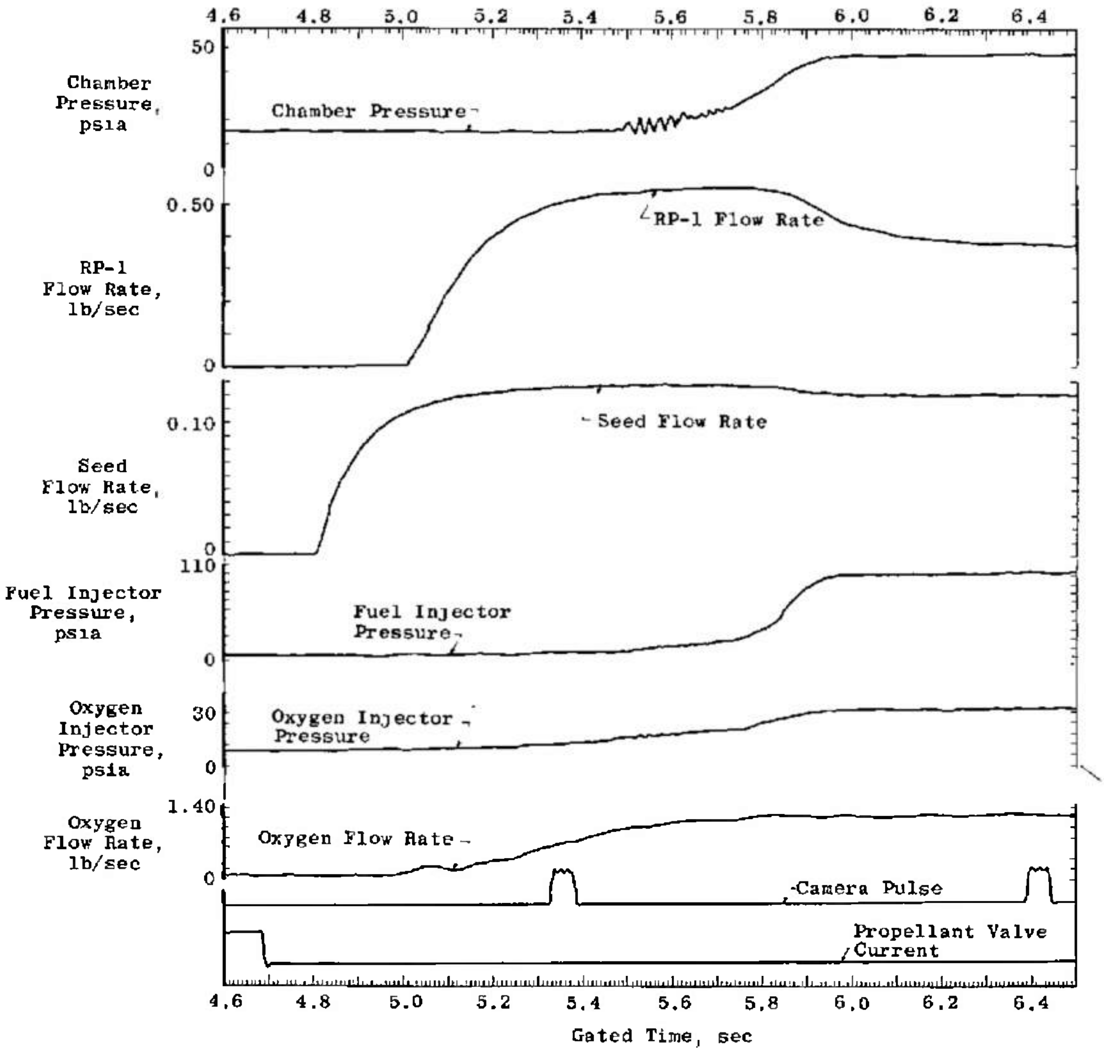


Fig. 23 Typical Engine Ignition Transient

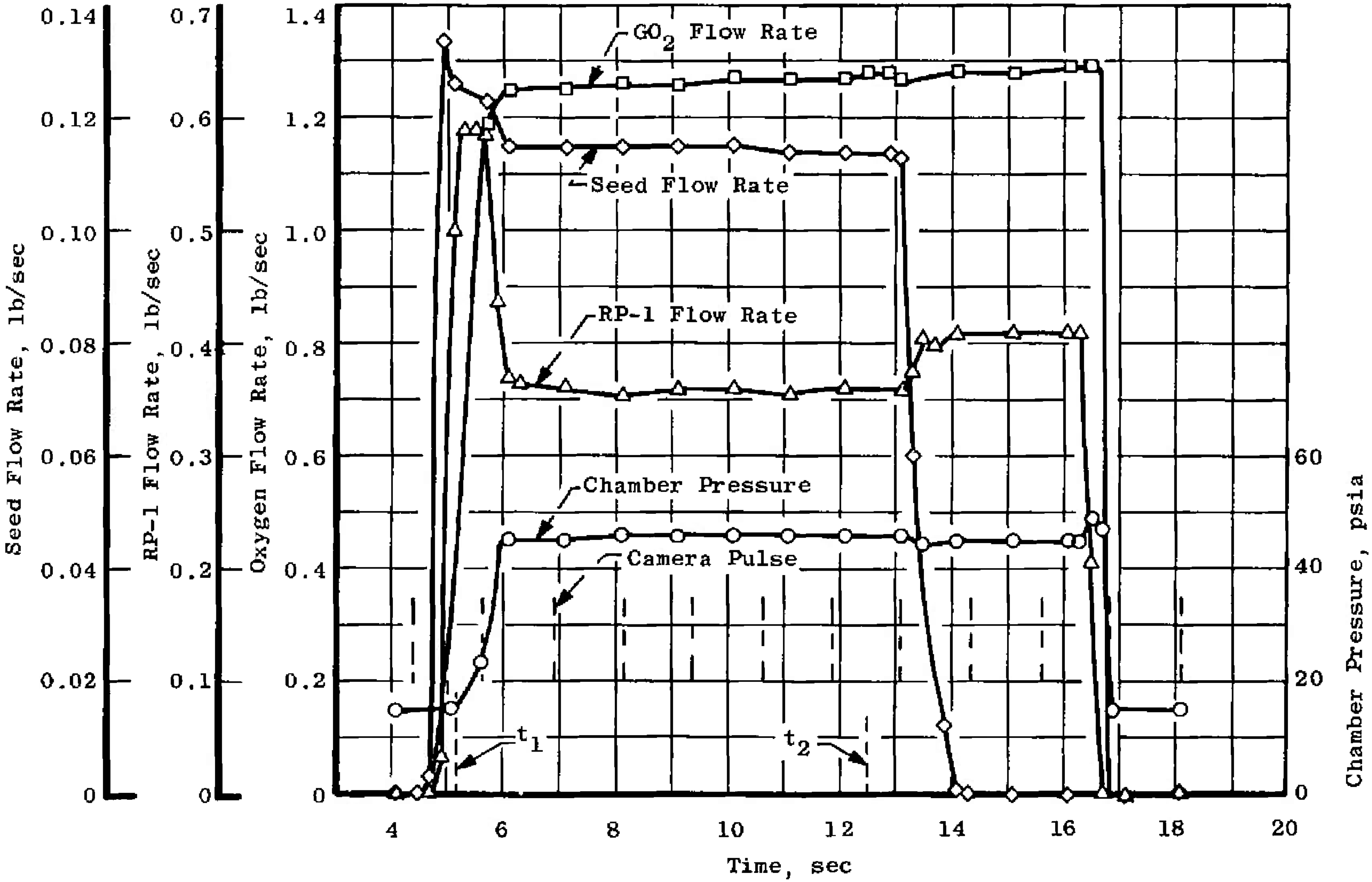


Fig. 24 Variation in Combustor Chamber Pressure and Seed and Propellant Flow Rates during a Typical Firing

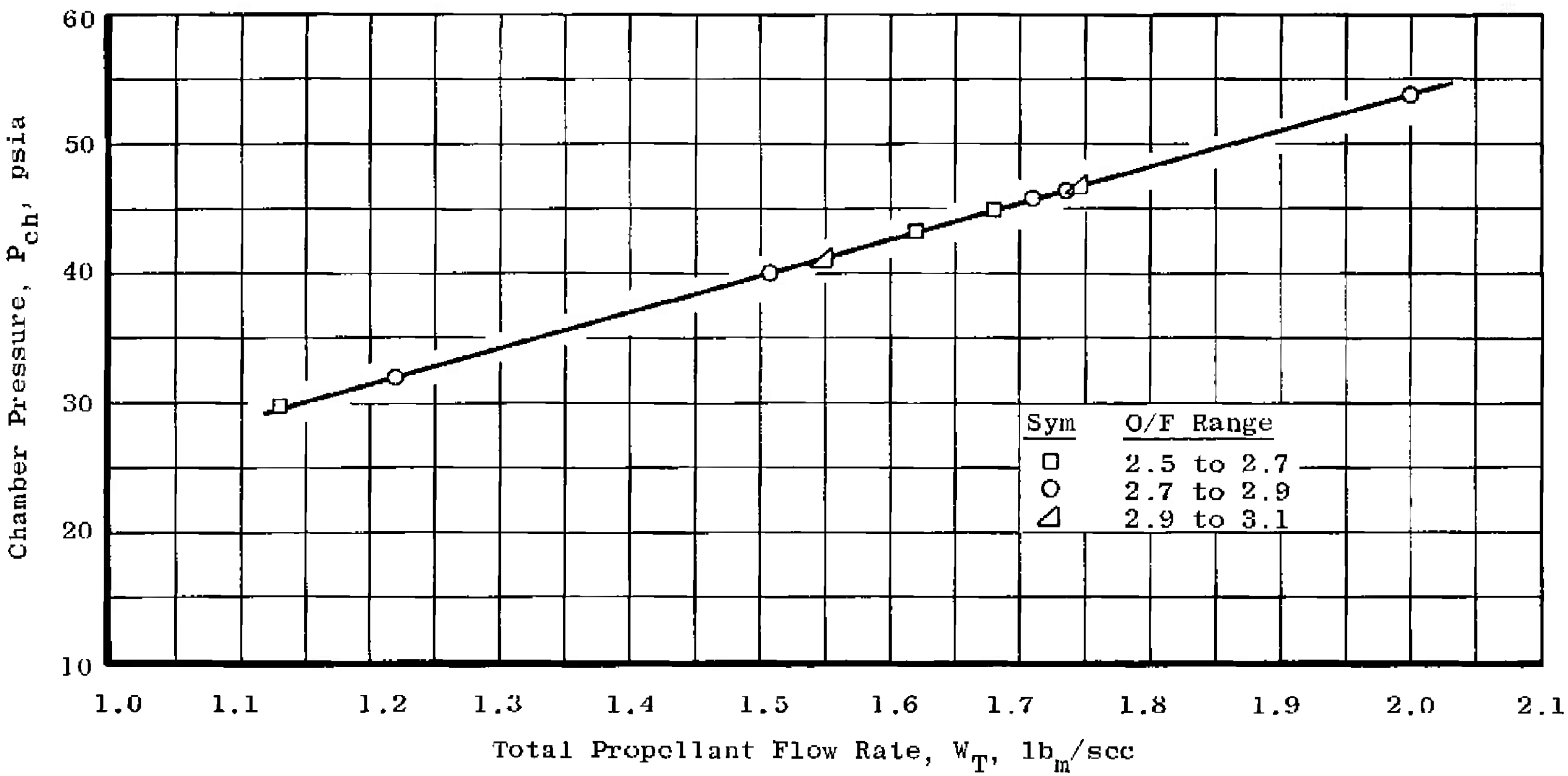
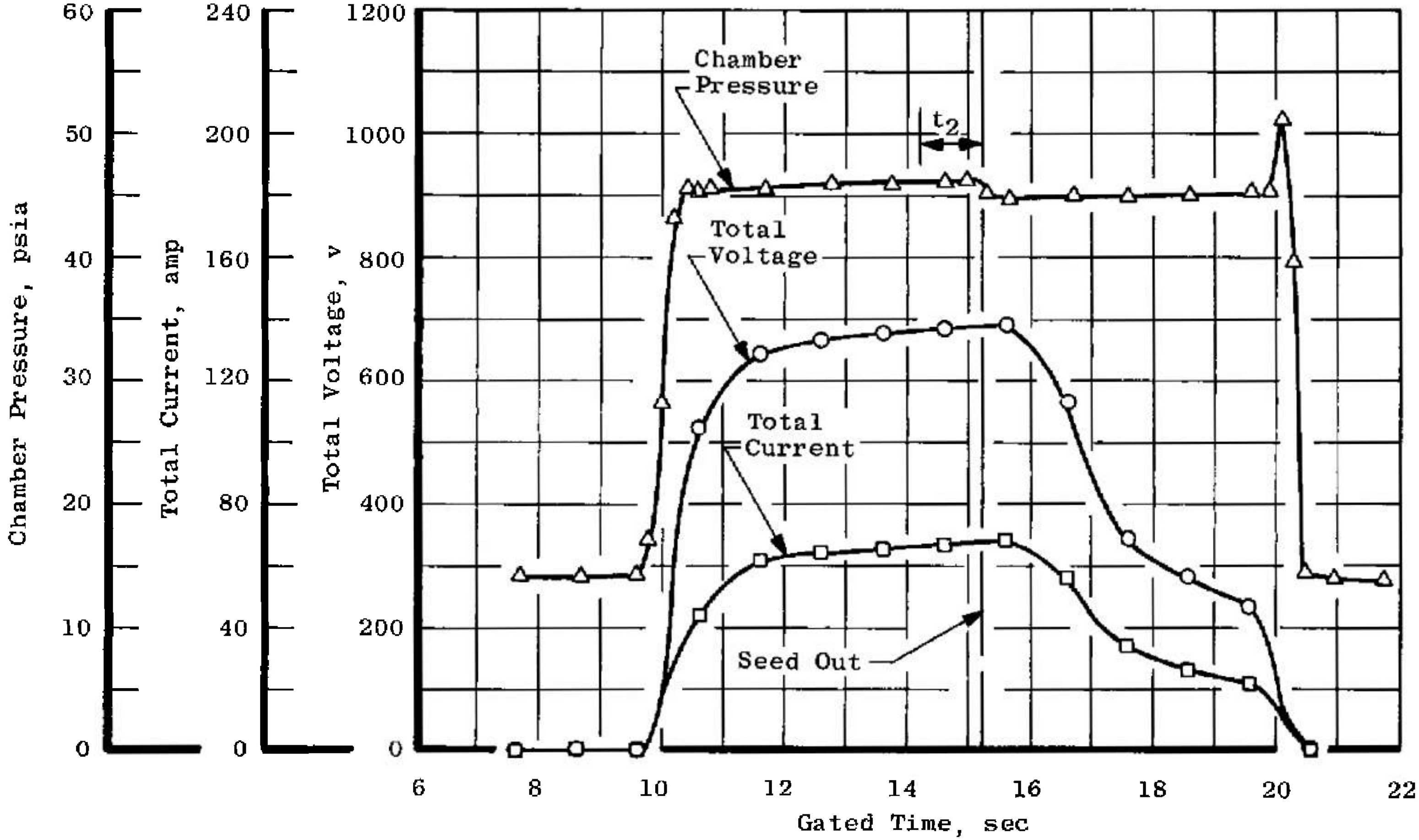
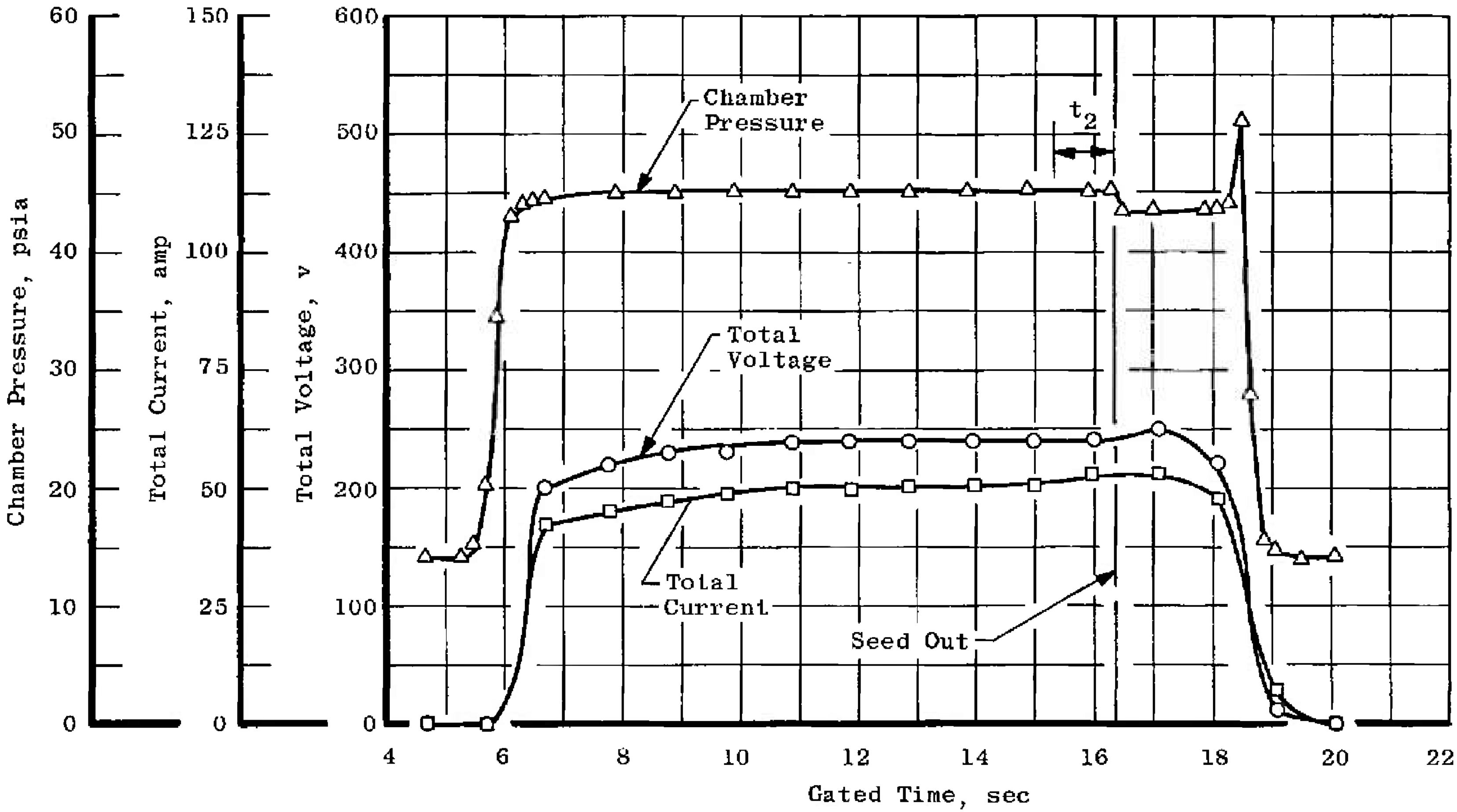


Fig. 25 Variation in Combustor Chamber Pressure as a Function of Total Propellant Flow Rate



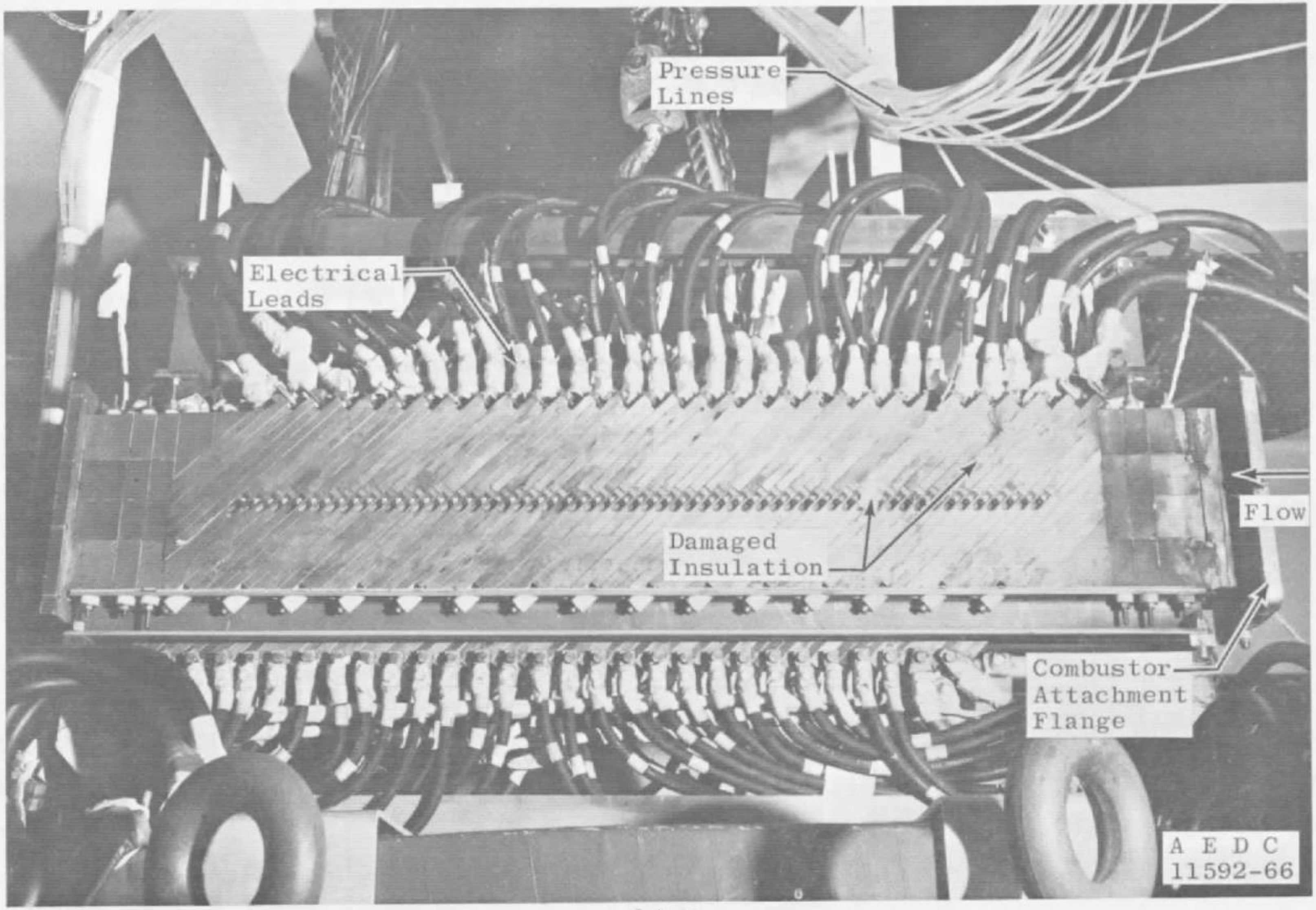
a. 45-deg Channel

Fig. 26 Plot Showing Chamber Pressure, Total Voltage, and Total Current Variation with Time for a Typical Firing



b. Hall Channel

Fig. 26 Concluded

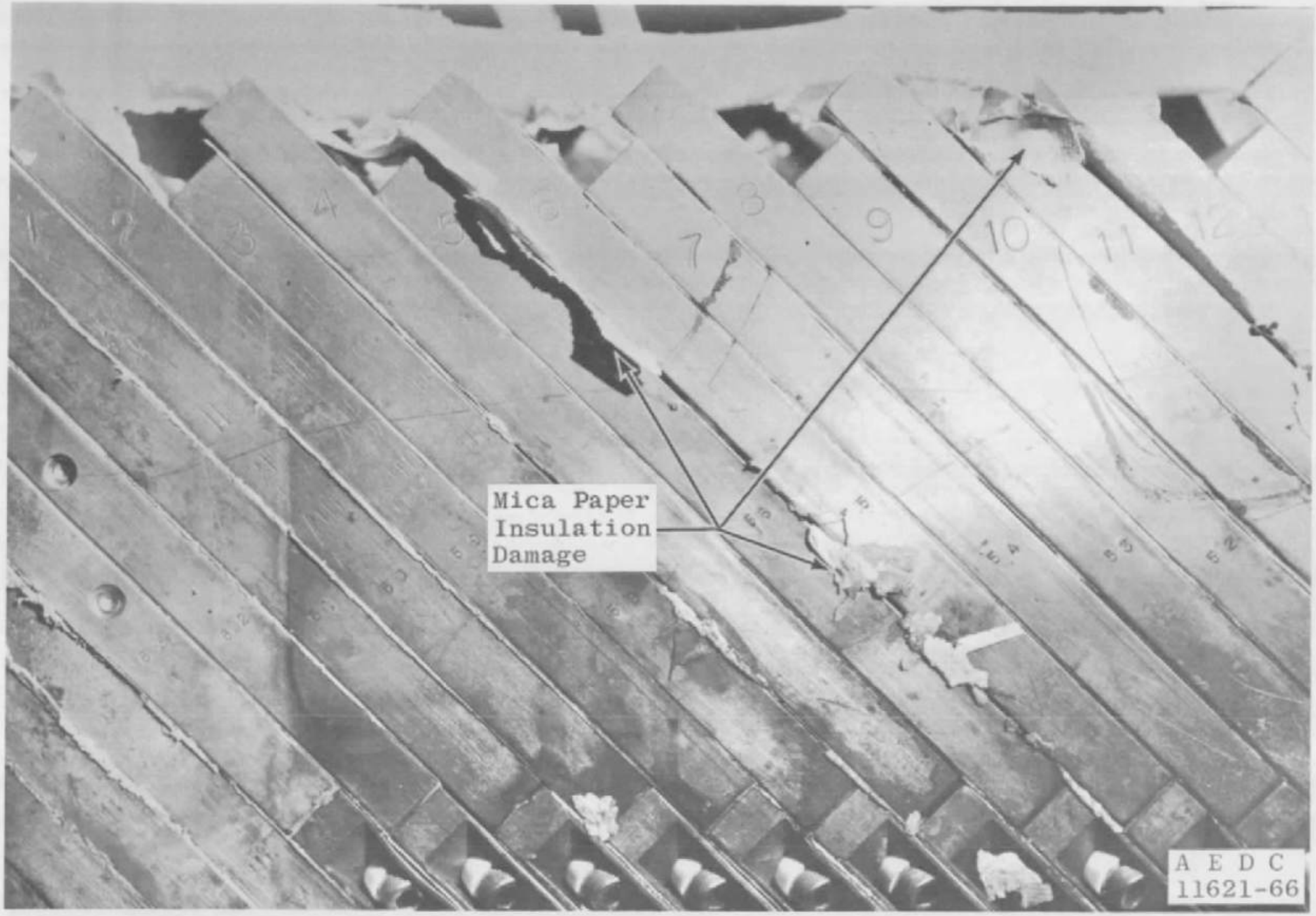


a. Side View

Fig. 27 Post-Fire Photographs of 45-deg Channel

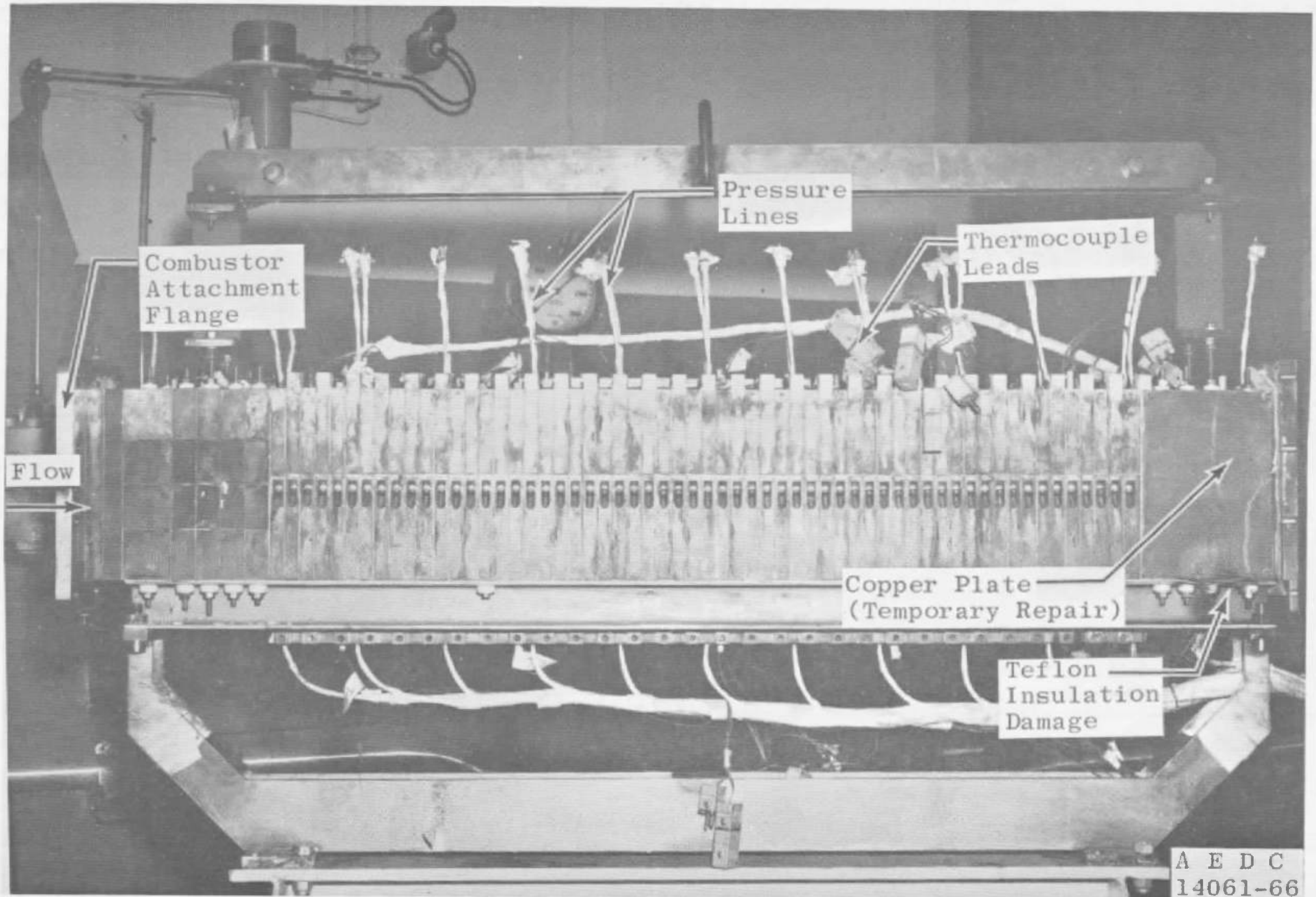
b. Detail View Showing Opening in the Upstream Transition Section

Fig. 27 Continued



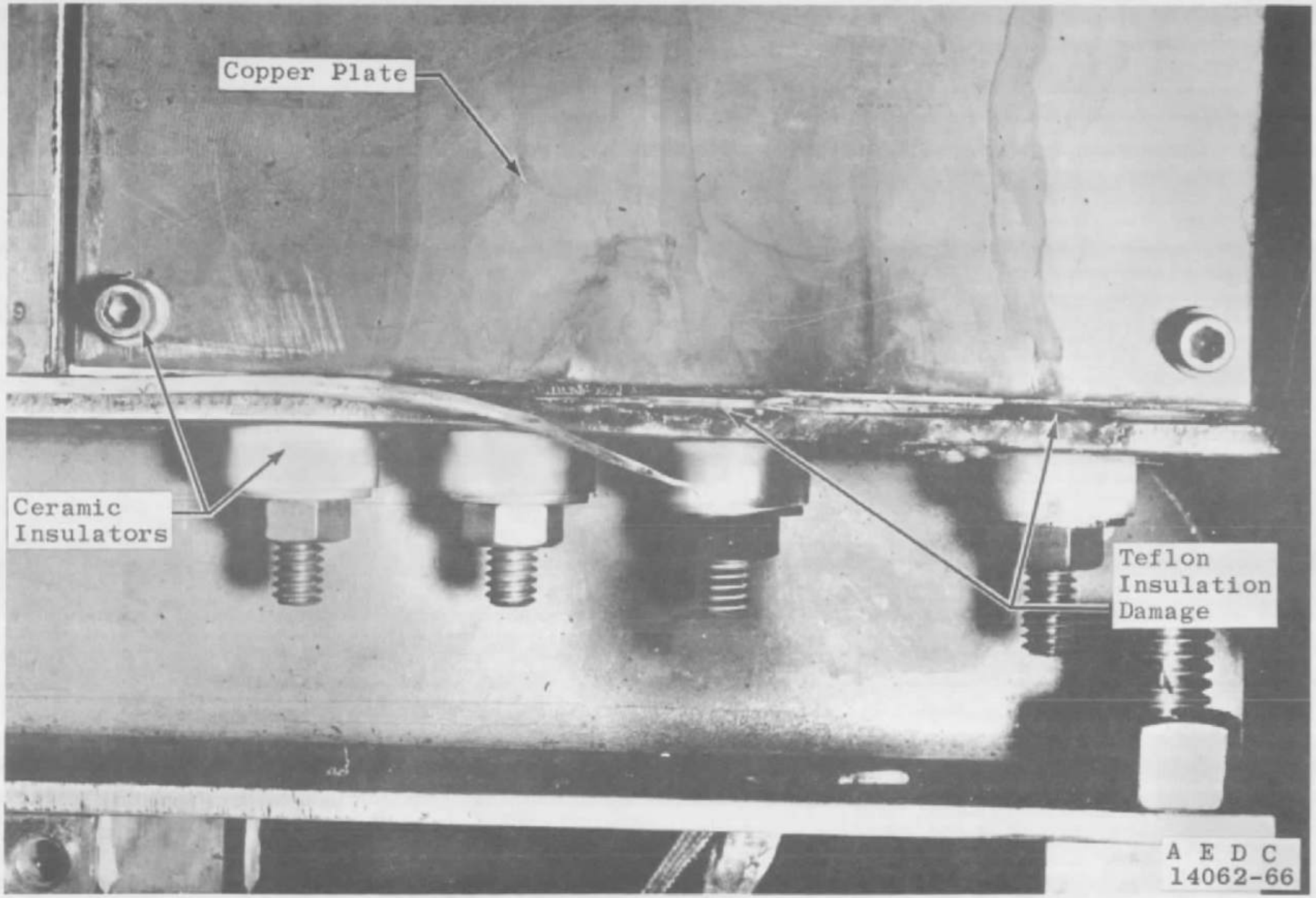
c. Detail View Showing Mica Paper Insulation Damage

Fig. 27 Concluded



a. Side View Showing Copper Plate Installed

Fig. 28 Post-Fire Photographs of Hall Channel



b. Detail View Showing Teflon Insulation Damage

Fig. 28 Concluded

TABLE I
INSTRUMENTATION

Parameter	Estimated Steady-State Systems Accuracy of Operating Level, percent	Measuring Device	Range of Measuring Device	Recording Method
Chamber Pressure	±0.75	Bonded Strain-Gage-Type Transducer	0-50 psia 0-100 psia	Millivolt-to-Frequency Converter onto Magnetic Tape
Venturi Upstream Pressure	±1	"	0-300 psia	"
RP-1 Flow Rate	±0.5	Turbine-Type Flowmeter	0-1.0 lb/sec	"
Seed Flow Rate	±0.5	"	0-0.16 lb/sec	"
Oxygen Flow Rate	±2	Venturi	---	"
Injector Pressures	±1	Bonded Strain-Gage-Type Transducer	0-200 psia 0-25 psia	"
Channel Pressure	±1	"	0-30 psia 0-50 psia	Low Level Multiplexed Analog-to-Digital Converter onto Magnetic Tape
Diffuser Pressure	±1	"	0-25 psia 0-50 psia	"
Nozzle Static Pressure	±1	"	0-25 psia	"
Rake Pressure	±1	"	0-100 psia	"
RP-1 Tank Pressure	±1	"	0-500 psia	"
Seed Tank Pressure	±1	"	0-500 psia	"
Channel Voltage	±1	Voltmeter	-20-100 v	Timer Actuated Camera onto 70-mm Film
Magnet Voltage	±1	"	0-120 v	"
Channel Current	±1	Ammeter	-20-100 a	"
Magnet Current	±1	"	0-2000 a	"
Channel Temperature	±20°C	Chromel-Alumel Thermocouples		"
Diffuser Temperature	±20°C	"		"
Time	---	Synchronous Timing Generator	---	Photographically Recording Galvanometer-Type Oscillograph

TABLE II
SUMMARY OF OPERATING CONDITIONS

Run Number*	Channel Configuration	Magnetic Field Strength, gauss	Nominal Chamber Pressure, psia	Load Bank Configuration Number	Measured Load Bank Total Resistance, ohms	Nominal Percent Seed
15.1	Hall	Aerodynamic Checkout Firings	40.7			15
15.2						15
15.3						15
15.4						15
16.1	45 deg		46.2			15
16.3						15
17.1						15
17.2		10,000		1	11.690	15
18.1		15,000		1		15
18.2		20,000		1		15
19.2		18,000		2	15.674	15
19.3		20,000		2		15
20.1		20,000		3	11.260	0
20.2		15,000		3		15
20.3		18,000		3		15
20.4		20,000		3		15
20.5		17,900		3		0
20.6		20,000		3		15
22.1		15,000		4	5.616	0
22.2		15,000		4		15
22.3		15,000		4		0
22.4		20,000		4		15
22.5		15,000		4		0
22.6		20,000	45.4	4		20
22.7		20,000	45.4	4		20
22.8		20,000	45.7	4		10
23.1		15,000	46.2	5	15.643	0
23.2		20,000		5		15
23.3		20,000		5		15
23.4		20,000	45.4	5		20
23.5		20,000	45.4	5		20
23.6		20,000	46.2	5		0
24.1		20,000		5		0
24.2		20,000		5		15
25.1	Hall	20,000	40.4	8	2.493	20
25.2		20,000		8		20
26.1		20,000		8		20
26.2		20,000		8		20
27.1		20,000	46.0	8		20
27.2		20,000		8		20
27.3		20,000		8		20
27.4		15,000		8		20
28.1		20,000		9	4.852	20
28.2		20,000		9		20
28.3		20,000		9		20
28.4		0		9		0
29.2		20,000		10	9.692	20
30.2		20,000		10		20
30.3		20,000		10		20
31.1		20,000		11	14.627	20
31.2		20,000		11		20
32.1		20,000		12	27.715	20

*Number to left of decimal denotes run sequence. Number after decimal denotes order of firings in each sequence.

TABLE III
SUMMARY OF COMBUSTOR PERFORMANCE

Run Number	t_1, sec	t_2, sec	Average Combustor Conditions at t_2				Burn Time, sec	
			P_{ch}, psia	W_{O_2}, pps	W_{RP-1}, pps	W_{seed}, pps	With Seed	Without Seed
15.1	9.3	12.6	40.7	1.159	0.321	0.078	4.4	3.0
15.2	9.7	12.8	41.1	1.122	0.328	---	4.0	2.4
15.3	9.9	17.2	41.3	1.176	0.318	0.078	8.2	3.2
15.4	9.5	22.8	41.5	1.186	0.316	0.079	14.2	2.6
16.1	9.5	14.2	43.9	1.283	0.345	0.086	5.6	4.0
16.3	9.3	14.4	45.1	1.292	0.341	0.084	6.0	3.0
17.1	10.7	15.4	45.1	1.246	0.380	0.084	5.8	1.6
17.2	8.7	13.2	45.4	1.270	0.380	0.084	5.6	2.4
18.1	9.2	14.1	46.6	1.294	0.380	0.086	5.8	2.2
18.2	9.8	14.3	46.5	1.290	0.380	0.086	5.4	2.4
19.2	10.3	15.2	46.9	1.319	0.371	0.088	5.8	2.0
19.3	10.5	15.2	47.0	1.315	0.373	0.088	5.8	1.8
20.1	9.7	15.8	46.1	1.297	0.449	0	0	7.8
20.2	9.7	15.0	46.2	1.292	0.374	0.087	7.8	1.4
20.3	9.5	14.2	46.3	1.293	0.374	0.088	5.6	2.6
20.4	9.5	14.6	46.2	1.294	0.374	0.088	6.0	1.8
20.5	9.5	14.2	46.7	1.292	0.439	---	5.6	5.6
20.6	9.5	14.4	46.2	1.290	0.376	0.088	5.8	5.4
22.1	9.7	16.8	47.1	1.334	0.448	0	0	8.4
22.2	9.5	14.4	46.7	1.326	0.369	0.087	5.8	2.8
22.3	9.7	16.6	46.7	1.329	0.448	0	0	8.4
22.4	9.7	14.4	46.2	1.303	0.371	0.087	5.6	2.8
22.5	9.7	16.6	46.6	1.309	0.448	0	0	8.2
22.6	9.7	14.2	45.8	1.293	0.347	0.113	5.4	2.6
22.7	9.7	14.2	45.7	1.287	0.345	0.113	5.4	3.2
22.8	9.7	14.6	46.3	1.300	0.398	0.056	5.6	2.8

TABLE III (Concluded)

Run Number	t_1, sec	t_2, sec	Average Combustor Conditions at t_2				Burn Time, sec	
			P_{ch}, psia	W_{O_2}, pps	W_{RP-1}, pps	W_{seed}, pps	With Seed	Without Seed
23.1	9.7	16.6	45.7	1.289	0.446	0	0	8.8
23 2	9.7	16.6	46.2	1.286	0.379	0.086	7.4	3.6
23 3	9.7	16.6	46.1	1.279	0.379	0.085	7.8	3.8
23 4	9.7	16.6	45.9	1.261	0.363	0 110	7.8	4.0
23.5	9.7	15.8	45.3	1.242	0.361	0.110	7.8	0
23.6	9.7	16.6	44 6	1.221	0.455	0	0	8.6
24.1	8.5	15.8	46.4	1.308	0.437	0	0	8.8
24.2	8.5	15 6	46 8	1.307	0.378	0.084	8.0	3.2
25.1	6.7	13.2	39.7	1.125	0.295	0.099	7.6	3.4
25.2	6.7	14.0	40 6	1.126	0.311	0.100	8.2	3 6
26.1	5.5	12.2	40.3	1.118	0.316	0.100	7.8	4.0
26 2	5 5	12.8	40.4	1.120	0.315	0.100	8.2	3 6
27.1	6.3	16.0	46.1	1 265	0.363	0.114	10 6	2.6
27.2	5.5	15.0	46 1	1 263	0.364	0.114	10.4	2.6
27.3	5.5	15.0	46.1	1.265	0.362	0.114	10.4	3.0
27.4	5.5	15.6	46.1	1.263	0.364	0.114	9.8	3.4
28.1	5.5	15.8	46.1	1.259	0.364	0.114	9.9	3 3
28.2	5.5	15.4	45.7	1.251	0.364	0.114	10.8	2.6
28.3	5.5	15 6	45.1	1.222	0 363	0.114	10.8	2.8
28.4	5 5	17 4	42.9	1.158	0.457	0	0	13 6
29.2	5.5	15.2	45.7	1.257	0.359	0.114	10.6	3.2
30.2	5 3	12.6	46.2	1 282	0.360	0.114	8.0	3.6
30.3	5.5	12.2	46.3	1.282	0.359	0.114	7.6	3.6
31 1	5.5	12.6	46.2	1 278	0 357	0.114	8.0	3.2
31.2	5.5	12.8	46.3	1.285	0.356	0.114	8.2	3.2
32.1	5.5	12.4	46.2	1.280	0 360	0.114	7 8	3.6

TABLE IV
SUMMARY OF MEASURED LOAD BANK RESISTANCES

Resistor Number	Measured Resistance, ohms									
	Config 1	Config 2	Config 3	Config. 4	Config. 5	Config 8	Config. 9	Config 10	Config. 11	Config. 12
R - 1	∞	0	0	0	0	0.0581	0.0581	0.114	0.1730	0.3445
2	0.12	0.172	0.129	0	0.172	0.0632	0.0632	0.125	0.1993	0.3869
3	0.14	0.200	0.141	0	0.199	0.0698	0.0698	0.137	0.1976	0.4635
4	0.21	0.232	0.156	0	0.232	0.0748	0.0748	0.148	0.2266	0.4502
5	0.17	0.231	0.155	0.0765	0.229	0.0847	0.0847	0.168	0.2543	0.4977
6	0.20	0.231	0.172	0.0871	0.229	0.0964	0.0964	0.190	0.2979	0.5873
7	0.20	0.233	0.176	0.0859	0.233	---	---	---	---	---
8	0.42	0.575	0.400	0.205	0.576	---	---	---	---	---
9	0.42	0.572	0.400	0.205	0.576	---	---	---	---	---
10	0.47	0.620	0.429	0.217	0.623	---	---	---	---	---
11	0.47	0.620	0.431	0.232	0.628	---	---	---	---	---
12	0.41	0.599	0.412	0.232	0.599	---	---	---	---	---
13	0.43	0.599	0.412	0.232	0.599	---	---	---	---	---
14	0.41	0.574	0.400	0.224	0.577	---	---	---	---	---
15	0.41	0.571	0.400	0.240	0.573	---	---	---	---	---
16	0.48	0.571	0.400	0.224	0.574	---	---	---	---	---
17	0.44	0.549	0.400	0.224	0.550	---	---	---	---	---
18	0.39	0.570	0.388	0.209	0.573	---	---	---	---	---
19	0.39	0.548	0.388	0.211	0.547	---	---	---	---	---
20	0.38	0.560	0.387	0.209	0.547	---	---	---	---	---
21	0.41	0.546	0.387	0.208	0.546	---	---	---	---	---

TABLE IV (Concluded)

Resistor Number	Measured Resistance, ohms									
	Config. 1	Config. 2	Config. 3	Config. 4	Config 5	Config 8	Config. 9	Config. 10	Config. 11	Config. 12
R - 22	0.38	0.500	0.378	0.197	0 502	---	---	---	---	---
23	0.43	0.500	0.365	0.187	0.503	---	---	---	---	---
24	0 37	0.480	0.355	0.183	0.483	---	---	---	---	---
25	0 34	0 480	0 355	0 182	0.483	---	---	---	---	---
26	0.37	0.467	0.350	0.173	0.466	---	---	---	---	---
27	0.41	0.467	0.349	0.173	0 467	---	---	---	---	---
28	0.34	0.467	0.328	0.174	0.467	---	---	---	---	---
29	0.32	0.471	0 329	0 175	0.466	---	---	---	---	---
30	0.31	0.400	0.351	0 175	0.400	0.0848	0.0848	0.166	0.2534	0.4963
31	0.31	0.400	0.310	0.174	0.400	0.0758	0.0758	0.149	0.2250	0.4523
32	0.32	0.382	0.299	0.151	0.383	0 0679	0.0679	0 133	0.1919	0.3733
33	0 30	0.382	0 281	0.134	0.382	0 0616	0 0616	0 121	0.1921	0.3737
34	0.13	0.221	0.200	0.0611	0.191	0.0563	0.0563	0.110	0.1677	0.3381
35	0.15	0.170	0.112	0.0560	0.167	0.0520	0.0520	0.101	0.1483	0.3171
36	0.09	0.170	0.102	0.0530	0.167	---	---	0.060	0.0896	0.1788
37	0.07	0.136	0.089	0.0465	0.134	---	---	---	---	---
38	0.04	0.120	0 072	0	0.111	---	---	---	---	---
39	0.04	0.088	0.072	0	0.089	---	---	---	---	---
40	0	0	0	0	0	---	---	---	---	---
41	0	0	0	0	0	---	---	---	---	---
R Center	---	---	---	---	---	1 648	4.007	7.97	12.01	22.455

TABLE V
LOCATION OF CHANNEL PRESSURE AND TEMPERATURE SENSING ELEMENTS

Parameter	45-deg Diagonal Channel			Hall Channel		
	Element Number	Axial Position, x, in *	Radial Position	Element Number	Axial Position, x, in. *	Radial Position
P1	Upstream End Transition Element	2.5	B	Upstream End Transition Element	2.5	T
P2		2.5	T	1	8.5	T
P3	B	8.4	B	1	8.5	S
P4	1	8.3	T	1	8.5	B
P5	4	10.1	T	6	11.5	T
P6	8	12.5	T	6	11.5	S
P7	3	13.9	B	6	11.5	B
P8	8	13.8	S	12	15.1	T
P9	11	14.4	T	12	15.1	S
P10	14	16.2	T	12	15.1	B
P11	18	18 6	T	18	18.7	T
P12	13	20.3	B	18	18.7	S
P13	18	20.0	S	18	18.7	B
P14	21	20.4	T	24	22.3	T
P15	24	22.2	T	24	22.3	S
P16	28	24.6	T	24	22.3	B
P17	23	26.5	B	30	25.9	T
P18	28	26 1	S	30	25.9	S
P19	31	26.5	T	30	25.9	B
P20	34	28.3	T	36	29.4	T
P21	37	30.1	T	36	29.4	S
P22	32	32 2	B	36	29.4	B
P23	37	31 6	S	42	33.0	T

T - Top
B - Bottom
S - Side
* Distance from Nozzle Exit Plane

TABLE V (Continued)

Parameter	45-deg Diagonal Channel			Hall Channel		
	Element Number	Axial Position, x, in.*	Radial Position	Element Number	Axial Position, x, in.*	Radial Position
P24	40	31.9	T	42	33.0	S
P25	43	33.7	T	42	33.0	B
P26	47	36.1	T	48	36.6	T
P27	42	38.5	B	48	36.6	S
P28	47	37.8	S	48	36.6	B
P29	50	37.9	T	54	40.2	T
P30	A	39.7	T	54	40.2	S
P31	E	42.1	T	54	40.2	B
P32	51	44.2	B	60	43.8	T
P33	D	43.4	S	60	43.8	S
P34	H	43.8	T	60	43.8	B
P35	Downstream End Transition Element	49.7	B	Downstream End Transition Element	49.7	T
P36		49.7	T		49.7	B
P37	Diffuser	54.0	T	Diffuser	54.0	T
P38	↓	56.3	T	↓	56.3	T
P39	↓	67.1	T	↓	67.1	T
P40	↓	73.8	T	↓	73.8	T
PNS1	Nozzle Exit Flange	---	B	Nozzle Exit Flange	---	B
PNS2	↓	---	S	↓	---	S
PNS3	↓	---	S	↓	---	S
PNS4	↓	---	T	↓	---	T
PEX-1	Pressure Rake	54.3	T	Pressure Rake	54.3	T
PEX-2	↓	↓	Center	↓	↓	Center
PEX-3	↓	↓	S	↓	↓	S

T - Top
B - Bottom
S - Side
*Distance from Nozzle Exit Plane

TABLE V (Concluded)

Parameter	45-deg Diagonal Channel			Hall Channel		
	Element Number	Axial Position, x, in.*	Radial Position	Element Number	Axial Position x, in.*	Radial Position
PEX-4	Pressure Rake	54.3	S	Pressure Rake	54.3	S
PEX-5	↓	↓	B	↓	↓	B
PDE-1 PDE-2	Spray Chamber	---	---	Spray Chamber	---	---
T1	Upstream End Transition Element	3.7	T	Upstream End Transition Element	3.7	T
T2	C	8.0	B	5	10.9	T
T3	2	8.9	T	5	10.9	S
T4	10	13.8	T	5	10.9	B
T5	12	19.6	B	17	18.1	T
T6	17	19.3	S	17	18.1	S
T7	20	19.8	T	17	18.1	B
T8	22	25.9	B	31	26.4	T
T9	27	25.4	S	31	26.4	S
T10	30	25.9	T	31	26.4	B
T11	31	31.6	B	43	33.6	T
T12	36	31.0	S	43	33.6	S
T13	39	31.3	T	43	33.6	B
T14	49	37.4	T	55	40.8	T
T15	50	43.6	B	55	40.8	S
T16	C	42.7	S	55	40.8	B
T17	G	43.3	T	Downstream Transition	48.6	T
T18	Downstream Transition	48.6	T	Downstream Transition	48.6	B
T19	Diffuser	53.8	T	Diffuser	53.8	T
T20	Diffuser	67.0	T	Diffuser	67.0	T

T - Top
B - Bottom
S - Side
*Distance from Nozzle Exit Plane

TABLE VI
SUMMARY OF CHANNEL PRESSURE MEASUREMENTS

Run Number	*Time, t_2, sec	Diffuser Total Pressures, psia					Nozzle Exit Static Pressures, psia				Channel Static Pressures, psia														
		PEX-1	PEX-2	PEX-3	PEX-4	PEX-5	PNS-1	PNS-2	PNS-3	PNS-4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
15.1	12.6	27.3	27.1	22.7	20.3	30.7	11.6	11.2	11.6	11.9	---	11.0	12.0	13.1	13.2	13.0	11.7	10.5	12.2	12.6	11.6	11.5	11.3	10.4	10.9
15.2	12.8	27.1	26.4	---	---	---	12.0	11.3	11.9	12.0	---	11.2	11.8	13.2	13.4	13.3	11.9	10.7	12.5	12.8	11.8	11.6	11.6	10.8	11.2
15.3	17.2	---	---	---	---	---	---	11.4	11.8	12.4	---	11.3	10.9	13.1	13.4	13.5	11.6	10.6	12.3	12.2	11.6	11.2	11.3	---	10.7
15.4	22.8	---	---	---	---	---	---	11.3	12.1	12.4	---	11.6	11.4	13.4	12.9	13.0	---	---	---	---	11.6	11.1	11.4	---	10.6
16.1	14.2	30.4	---	---	24.7	29.3	---	12.5	13.6	13.2	12.3	13.1	---	---	---	12.6	13.4	---	12.8	11.1	10.1	---	12.2	13.1	10.1
16.3	14.4	31.3	---	---	25.4	29.8	---	12.7	13.9	13.3	12.9	13.1	14.6	---	---	13.1	13.8	---	13.4	10.9	10.4	---	12.7	12.0	10.6
17.1	15.4	29.4	---	22.6	21.4	33.5	11.8	12.5	13.2	13.7	11.5	12.6	14.7	14.3	11.3	13.0	13.5	13.3	12.7	10.5	10.9	14.9	12.5	12.1	10.5
17.2	13.2	29.0	---	22.7	21.7	32.5	---	---	---	---	11.6	12.8	14.5	14.2	12.2	13.2	13.7	13.6	12.9	10.8	11.4	15.3	12.7	12.4	10.7
18.1	14.1	28.8	---	23.2	22.6	31.4	---	---	---	---	12.1	13.1	14.9	14.4	12.7	13.6	14.0	14.2	13.4	12.1	11.9	15.7	12.8	13.3	11.0
18.2	14.3	26.5	---	22.6	22.9	29.2	---	---	---	---	12.0	13.1	14.8	14.3	12.7	13.7	14.3	14.4	13.5	11.7	12.7	16.2	13.2	13.7	11.6
19.2	15.2	27.6	---	23.4	22.9	29.4	---	---	---	---	11.8	---	14.7	---	---	13.8	14.1	14.5	---	---	12.5	15.7	13.1	---	11.3
19.3	15.2	26.1	---	23.2	22.8	27.8	---	---	---	---	11.9	---	14.7	---	---	13.7	14.1	14.5	---	---	12.7	15.9	13.1	---	11.4
20.1	15.8	29.4	---	23.0	21.6	33.3	---	---	---	---	11.6	---	14.2	---	---	12.9	13.4	14.4	---	---	11.4	16.1	12.8	---	10.4
20.2	15.0	28.5	---	22.7	22.1	30.9	---	---	---	---	11.9	---	14.6	---	---	13.4	13.7	13.9	---	---	11.9	15.4	12.6	---	10.8
20.3	14.3	26.4	---	22.7	22.2	28.2	---	---	---	---	12.0	---	14.4	---	---	13.5	13.8	14.0	---	---	12.3	15.6	12.7	---	11.0
20.4	14.6	25.8	---	22.2	22.4	26.5	---	---	---	---	12.1	---	14.5	---	---	13.4	14.0	14.1	---	---	12.4	16.0	13.1	---	11.4
20.5	14.2	28.8	---	22.7	22.3	30.9	---	---	---	---	12.1	---	14.4	---	---	13.2	14.0	14.6	---	---	11.9	16.2	13.0	---	10.7
20.6	14.4	25.9	---	22.2	22.4	28.4	---	---	---	---	12.2	---	14.6	---	---	14.1	14.0	14.2	---	---	12.4	16.0	13.2	---	11.4
22.1	16.8	31.4	---	24.7	22.7	33.7	---	13.1	14.0	13.7	12.1	---	14.0	---	---	---	13.9	14.2	---	---	---	16.7	12.9	---	10.6
22.2	14.4	28.9	---	23.6	22.5	30.2	---	12.8	---	13.5	12.3	---	14.2	---	---	13.6	13.3	13.4	---	---	---	15.4	12.6	---	11.1
22.3	16.6	31.3	---	24.9	22.8	33.4	---	13.0	---	13.7	12.3	---	13.7	---	---	---	13.8	14.0	---	---	---	16.5	12.9	---	10.5
22.4	14.4	25.3	---	23.2	22.4	26.1	---	12.8	---	13.6	12.5	---	14.3	---	---	---	13.8	14.0	---	---	---	15.9	13.3	---	11.5
22.5	16.6	31.3	---	25.0	22.7	33.4	---	13.0	---	13.7	13.0	---	13.7	---	---	---	13.7	14.3	---	---	---	16.5	13.0	---	10.4
22.6	14.2	24.9	---	22.8	22.2	25.5	---	12.6	---	13.4	12.6	---	14.2	---	---	---	13.4	13.7	---	---	---	15.4	13.2	---	11.5
22.7	14.2	25.2	---	22.7	22.0	27.6	---	12.6	---	13.4	12.7	---	14.2	---	---	---	13.9	13.5	---	---	---	15.5	13.1	---	11.4
22.8	14.6	26.4	---	23.5	22.2	28.4	---	12.7	---	13.6	12.8	---	14.4	---	---	---	14.0	14.2	---	---	---	16.0	13.2	---	11.2
23.1	16.6	30.5	---	23.9	21.8	32.6	---	12.7	---	13.1	12.2	---	13.4	---	---	---	13.6	---	---	---	---	16.1	12.8	---	10.3
23.2	16.6	25.5	---	23.3	22.1	26.7	---	12.7	---	13.2	12.7	---	14.2	---	---	---	13.8	---	---	---	---	15.8	13.2	---	11.5
23.3	16.6	26.0	---	23.0	22.4	28.2	---	12.7	---	13.3	12.8	---	14.0	---	---	---	14.0	---	---	---	---	16.1	13.2	---	11.5
23.4	16.6	25.5	---	22.9	22.3	27.8	---	12.5	---	13.4	12.9	---	13.8	---	---	---	14.0	---	---	---	---	15.9	13.1	---	11.6
23.5	15.8	25.2	---	22.4	22.0	27.8	---	12.4	---	13.2	12.7	---	13.7	---	---	---	13.8	---	---	---	---	15.8	13.0	---	11.6
23.6	16.6	28.1	---	28.8	21.7	31.1	---	12.4	---	13.1	12.4	---	12.9	---	---	---	13.3	---	---	---	---	15.7	12.5	---	10.1
24.1	15.8	31.3	30.7	25.7	22.4	32.1	---	12.8	---	13.4	12.8	---	13.5	---	---	---	13.7	---	---	---	---	16.1	13.0	---	10.3
24.2	15.6	25.8	26.2	23.7	22.3	27.3	---	12.8	---	13.6	13.0	---	14.2	---	---	---	14.2	---	---	---	---	15.9	13.5	---	11.6

*See Fig. 24.

TABLE VI (Continued)

Run Number	*Time, t_2, sec	Channel Static Pressure, psia																					Diffuser Static Pressure, psia				Spray Chamber Pressure, psia	
		P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	PDE-1	PDE-2
15.1	12.6	11.5	10.9	10.1	10.5	10.2	10.9	10.5	10.2	9.92	9.98	9.56	10.2	9.52	9.08	9.11	9.43	10.9	8.48	9.17	14.7	14.8	15.5	18.3	13.9	14.2	14.3	14.3
15.2	12.6	11.8	11.1	10.3	10.8	10.4	11.1	10.5	10.3	10.1	10.1	9.79	10.5	9.67	9.20	9.39	9.67	11.1	6.56	9.61	14.3	14.3	15.1	16.3	13.8	14.2	14.3	14.3
15.3	17.2	11.1	10.7	10.1	10.8	10.2	10.7	10.1	9.57	9.92	10.1	9.62	10.2	9.31	9.17	8.82	9.19	11.1	8.11	8.90	14.4	14.4	15.2	18.3	14.1	14.4	14.4	14.4
16.4	22.6	10.6	---	10.1	---	---	---	9.50	---	9.81	10.0	---	10.0	---	9.24	9.12	---	11.0	8.09	8.48	13.6	13.5	14.7	17.8	14.1	14.4	14.4	14.4
16.1	14.2	12.7	12.7	12.7	11.2	8.05	11.2	11.2	11.7	12.0	11.0	9.85	10.9	10.6	8.36	---	10.2	11.0	---	9.56	15.0	15.4	15.8	21.3	13.6	14.1	14.3	14.2
16.3	14.4	12.9	12.9	13.2	11.1	8.13	11.4	11.3	12.1	12.1	11.1	10.0	11.0	10.8	8.66	---	10.2	11.0	---	9.77	14.7	15.2	17.8	22.3	13.6	14.2	14.3	14.3
17.1	15.4	12.6	12.2	12.7	11.0	7.90	11.2	10.9	11.8	11.7	11.0	10.0	10.7	10.3	8.73	---	10.1	10.4	---	9.40	14.0	14.4	16.6	21.5	13.4	14.2	14.3	14.3
17.2	12.2	12.7	12.8	13.0	11.4	8.44	11.3	11.0	12.2	12.0	11.3	10.5	11.0	10.8	8.80	---	10.7	10.8	---	10.0	14.7	15.1	18.0	21.9	13.8	14.2	14.3	14.3
18.1	14.1	13.1	14.2	12.7	12.2	9.57	12.3	12.0	12.6	12.8	11.6	11.5	11.4	11.8	9.85	---	11.9	11.1	---	10.0	16.2	18.4	---	---	12.8	14.4	14.5	14.5
18.2	14.3	12.2	14.7	14.3	13.3	11.7	13.8	14.3	13.2	13.6	13.3	13.3	12.7	13.4	12.9	---	15.2	15.6	---	16.2	16.7	16.8	---	---	13.8	14.4	14.5	14.5
19.2	15.2	---	14.4	13.8	---	10.4	13.5	13.1	12.8	---	12.4	13.9	12.1	12.4	11.2	---	12.2	14.9	---	14.6	16.0	16.4	---	---	13.5	14.2	14.3	14.3
19.3	15.2	---	14.3	14.1	---	11.2	13.7	13.8	13.2	---	13.2	13.4	12.5	13.2	12.1	---	15.0	15.6	---	16.3	16.5	16.3	---	---	13.5	14.2	14.4	14.4
20.1	15.8	---	12.7	12.6	---	8.45	11.3	10.7	11.8	---	11.5	10.4	10.8	10.9	9.15	---	10.3	10.8	---	9.41	14.0	14.3	---	---	13.6	14.2	14.4	14.4
20.2	15.0	---	13.6	13.2	---	9.38	11.7	11.4	12.3	---	11.3	11.2	11.2	11.5	9.93	---	11.5	11.0	---	10.6	15.8	15.6	---	---	13.7	14.3	14.4	14.4
20.3	14.2	---	14.1	13.8	---	10.3	13.1	13.3	12.5	---	12.2	12.8	12.1	13.4	11.3	---	12.0	14.2	---	14.2	16.1	15.8	---	---	13.7	14.3	14.4	14.4
20.4	14.6	---	14.3	14.1	---	11.4	13.5	14.1	13.0	---	13.3	12.0	12.5	12.4	12.6	---	14.5	13.2	---	15.4	16.0	15.0	---	---	13.7	14.3	14.4	14.4
20.5	14.2	---	14.3	12.7	---	9.65	12.9	12.4	12.4	---	11.6	12.2	11.4	11.8	10.2	---	11.6	11.3	---	10.8	15.5	15.5	---	---	13.5	14.3	14.4	14.4
20.6	14.4	---	14.2	14.1	---	11.5	13.5	14.2	13.1	---	12.4	12.1	12.7	13.5	12.0	---	14.7	15.3	---	15.3	16.0	15.7	---	---	13.7	14.3	14.4	14.4
22.1	16.8	---	13.7	13.3	---	8.98	11.8	11.1	12.1	---	11.8	10.5	10.7	11.0	10.8	---	10.6	11.5	---	9.52	11.9	12.0	15.3	18.0	13.8	14.2	---	14.3
22.2	14.4	---	13.5	13.6	---	9.64	11.9	11.6	12.4	---	11.5	11.5	11.0	11.5	11.2	---	11.8	11.3	---	10.6	14.9	15.1	15.2	18.3	13.5	14.1	---	14.3
22.3	16.6	---	13.7	13.2	---	9.08	11.6	10.6	12.1	---	11.7	10.5	10.6	10.8	10.7	---	10.4	11.3	---	9.42	12.4	11.9	15.2	17.9	13.5	14.2	---	14.3
22.4	14.4	---	14.1	14.3	---	11.5	13.6	12.6	13.0	---	13.4	13.3	12.2	13.4	12.4	---	13.4	14.9	---	15.3	15.7	15.5	14.6	18.6	13.5	14.2	---	14.2
22.5	16.6	---	13.9	13.4	---	9.28	11.7	11.1	12.2	---	11.7	10.6	10.9	10.9	10.7	---	10.5	11.4	---	9.44	11.3	11.2	15.4	17.8	13.5	14.1	---	14.3
22.6	14.2	---	13.0	14.2	---	11.3	13.7	12.9	13.0	---	13.4	13.2	12.4	12.3	13.4	---	12.9	14.7	---	14.9	15.4	15.4	14.4	18.5	13.4	14.1	---	14.2
22.7	14.2	---	14.0	14.1	---	11.2	13.8	13.9	12.9	---	13.2	12.0	12.4	13.2	12.1	---	12.9	14.5	---	14.4	15.4	15.2	14.5	18.3	12.4	14.2	---	14.2
22.8	14.6	---	14.2	14.3	---	10.6	13.6	13.8	12.8	---	12.8	---	12.2	12.7	---	---	12.2	13.3	---	12.8	16.4	16.4	14.7	18.5	13.4	14.1	---	14.3
23.1	16.6	---	13.8	---	---	9.10	11.5	11.0	12.0	---	11.5	10.4	10.7	10.8	10.5	---	10.4	11.3	---	9.34	11.2	10.8	15.0	17.3	13.6	14.2	---	14.3
22.2	16.6	---	14.0	---	---	11.4	13.6	14.0	13.0	---	12.3	13.3	12.4	13.4	12.4	---	12.0	14.8	---	14.6	15.3	15.9	14.4	18.3	12.6	14.2	---	14.3
23.3	16.6	---	14.3	---	---	11.6	13.6	14.1	13.0	---	13.3	13.1	12.6	13.6	12.4	---	13.2	14.7	---	14.6	15.4	15.7	14.7	18.0	12.6	14.3	---	14.3
22.4	16.6	---	14.2	---	---	11.9	13.7	14.5	13.3	---	14.0	12.6	13.3	13.8	13.8	---	14.2	14.9	---	14.0	15.3	15.7	14.7	17.9	13.5	14.2	---	14.3
23.5	16.6	---	14.0	---	---	11.8	13.7	14.8	13.2	---	13.8	13.4	13.2	13.7	13.7	---	14.1	14.7	---	14.6	15.2	15.5	14.5	17.7	13.5	14.2	---	14.2
23.6	16.8	---	12.9	---	---	9.14	11.8	10.8	11.8	---	11.3	10.9	10.8	10.8	10.3	---	11.0	11.0	---	9.75	11.6	10.8	14.4	16.8	13.6	14.2	---	14.3
24.1	15.8	---	13.7	---	---	9.28	11.7	10.8	12.1	---	11.6	10.5	10.8	10.9	10.7	---	10.8	11.2	---	9.43	12.5	11.3	15.3	17.6	13.7	14.3	---	14.4
24.2	15.6	---	14.3	---	---	11.4	13.9	14.0	13.1	---	13.2	13.4	12.5	13.3	13.3	---	12.8	13.9	---	13.5	15.4	15.8	14.1	18.5	13.8	14.4	---	14.5

*See Fig. 24.

TABLE VI (Continued)

Run Number	*Time, l_2, sec	Diffuser Total Pressures, psia					Nozzle Exit Static Pressures, psia				Channel Static Pressures, psia														
		PEX-1	PEX-2	PEX-3	PEX-4	PEX-5	PNS-1	PNS-2	PNS-3	PNS-4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
25.1	13.2	22.1	23.3	20.6	19.5	22.3	11.4	14.1	10.6	11.4	11.5	9.66	9.98	13.4	13.2	12.0	10.0	10.2	10.4	12.5	12.0	12.2	10.8	11.6	10.9
25.2	14.0	22.1	23.9	21.1	20.2	22.6	12.1	13.9	10.9	11.7	11.9	10.0	10.3	13.8	13.6	12.8	10.5	10.6	10.9	12.8	12.8	13.0	11.1	12.6	12.3
26.1	12.2	22.2	23.0	20.9	19.9	23.1	---	14.0	10.7	11.7	---	9.98	10.2	13.4	13.4	12.7	10.3	10.3	10.9	12.8	12.4	12.8	10.8	11.7	11.3
26.2	12.8	21.8	22.5	20.6	19.9	23.3	---	13.9	10.6	11.9	---	---	10.7	13.5	13.5	12.4	10.3	10.3	---	12.9	12.8	13.0	10.9	12.1	11.7
27.1	16.0	24.7	25.4	22.9	22.4	28.1	---	---	11.8	13.5	---	---	---	---	---	14.2	11.9	11.7	---	14.6	14.3	14.7	12.5	13.2	12.9
27.2	15.0	24.3	25.0	23.0	22.5	27.2	---	---	11.8	13.8	---	---	---	---	---	14.7	11.9	11.8	---	14.7	14.8	15.2	12.8	14.8	13.9
27.3	15.0	24.2	24.9	23.1	22.3	27.1	---	---	11.8	13.6	---	---	---	---	---	14.7	11.8	---	---	14.6	14.8	15.3	12.6	14.4	---
27.4	15.6	26.4	27.0	23.7	21.9	29.4	---	---	11.7	13.7	---	---	---	---	---	14.7	---	---	---	14.5	---	---	12.3	---	---
28.1	15.8	24.1	25.0	23.0	22.6	26.7	---	---	11.7	13.7	---	---	---	---	---	---	---	---	---	---	---	---	13.0	---	---
28.2	15.4	23.9	24.7	22.9	22.5	26.5	---	---	11.5	13.6	---	---	---	---	---	14.8	---	---	---	15.0	---	---	13.7	---	---
28.3	15.6	23.6	24.8	22.6	22.1	26.3	---	---	11.3	13.4	---	---	---	---	---	14.6	---	---	---	14.7	---	---	13.2	---	---
28.4	17.4	29.0	28.3	22.2	22.5	31.3	---	---	10.7	12.9	---	---	---	---	---	13.7	---	---	---	13.2	---	---	13.1	---	---
29.2	15.2	25.0	25.9	22.9	21.9	26.9	---	---	11.6	---	---	---	---	---	---	14.3	11.9	11.9	12.6	---	---	---	13.5	---	---
30.2	12.6	25.2	25.9	23.0	22.1	27.8	12.7	14.0	12.3	10.9	13.4	12.2	14.4	16.1	16.8	14.3	11.8	11.8	14.0	14.5	14.4	14.6	13.4	15.2	13.6
30.3	12.2	24.9	25.7	23.1	22.3	27.0	12.7	13.7	11.6	10.9	13.6	11.6	14.1	16.7	16.7	14.8	11.8	11.7	---	14.8	14.6	15.0	13.0	15.1	13.7
31.1	12.6	24.8	25.7	22.9	22.2	27.3	---	13.4	11.9	11.2	---	11.8	14.5	16.6	16.9	14.9	11.8	11.7	---	14.9	14.5	15.0	13.4	15.8	14.0
31.2	12.8	24.5	25.3	23.0	22.5	27.4	---	13.6	12.2	11.1	---	11.8	14.6	16.9	17.0	15.0	12.0	12.0	---	15.2	14.9	---	14.2	18.6	15.1
32.1	12.4	24.7	25.5	23.2	22.7	26.9	12.7	13.6	12.5	11.1	---	12.1	---	16.9	16.6	15.0	11.8	12.6	---	15.2	15.1	---	15.3	17.0	---

*See Fig. 24.

TABLE VI (Concluded)

Run Number	*Time t_2, sec	Channel Static Pressure, psia																					Diffuser Static Pressure, psia				Spray Chamber Pressure	
		P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30	P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	PDE-1, psia	PDE-2, psia
25.1	13.2	11.6	11.8	11.2	11.5	12.2	12.2	10.8	12.2	13.0	11.5	11.5	12.0	11.6	12.0	11.1	12.1	14.2	13.1	13.4	13.5	14.1	13.1	16.2	13.7	14.3	14.5	14.4
25.2	14.0	12.3	12.4	12.3	12.6	13.5	13.2	12.4	13.3	13.5	13.0	12.7	13.1	12.8	13.2	12.7	12.9	14.3	13.0	13.2	13.4	14.2	13.2	16.0	13.7	14.3	14.4	14.4
26.1	12.2	12.0	12.0	11.9	12.0	12.5	12.5	11.3	12.3	12.8	12.0	12.0	12.6	11.8	12.0	11.6	11.9	14.1	12.7	13.0	13.2	13.0	13.1	16.1	13.7	14.3	14.4	14.4
26.2	12.8	12.2	12.1	11.9	12.3	12.9	12.6	11.8	12.8	13.3	12.5	12.4	12.9	12.3	12.9	12.4	12.5	14.4	12.8	13.0	13.1	14.0	13.0	16.1	13.7	14.3	14.4	14.4
27.1	16.0	13.9	13.7	13.5	13.6	14.4	14.1	12.7	14.1	14.7	13.7	13.8	14.5	13.0	13.5	12.9	13.2	15.3	13.2	13.1	14.2	14.7	13.3	17.2	13.5	14.3	14.4	14.4
27.2	15.0	14.0	14.1	13.9	14.6	15.5	15.0	14.1	14.9	15.7	15.0	14.4	15.0	14.4	14.3	13.7	13.8	15.9	13.6	13.7	14.1	14.7	13.5	17.5	13.3	14.3	14.4	14.4
27.3	15.0	14.0	14.3	14.0	14.7	15.8	15.3	14.1	15.2	---	15.1	14.4	15.1	14.4	14.5	13.9	13.9	15.8	13.8	13.6	14.1	14.8	13.3	17.2	13.4	14.4	14.4	14.4
27.4	15.6	13.8	---	---	12.7	---	13.2	11.1	12.4	---	12.4	---	---	12.8	---	---	11.7	14.3	---	12.1	13.2	13.3	13.7	16.9	13.6	14.3	14.4	14.4
28.1	15.8	14.3	---	---	16.7	---	16.6	15.5	---	---	15.8	---	---	15.0	---	---	14.3	---	---	13.9	---	14.9	13.2	16.9	13.4	14.3	14.4	14.4
28.2	15.4	15.3	---	---	17.0	---	16.7	15.6	---	---	15.9	---	---	15.0	---	---	14.3	---	---	14.0	---	14.9	13.2	17.0	13.3	14.3	14.3	14.3
28.3	15.6	14.3	---	---	16.5	---	16.3	15.3	---	---	15.6	---	---	14.7	---	---	13.9	---	---	13.8	---	14.5	13.0	16.3	13.4	14.3	14.4	14.4
28.4	17.4	12.4	---	---	12.4	---	11.8	9.76	---	---	10.8	---	---	10.9	---	---	10.4	---	---	9.50	---	10.9	13.0	14.0	13.7	14.2	14.4	14.4
29.2	15.2	13.8	---	---	---	---	---	13.8	---	---	---	---	---	13.8	13.6	13.2	13.2	---	12.7	12.7	---	---	---	---	13.3	14.3	14.4	14.4
30.2	12.5	14.1	14.0	13.8	14.5	15.3	14.4	13.9	14.3	15.3	14.1	13.8	14.0	13.8	13.4	12.9	13.2	15.3	12.7	12.8	14.3	14.9	13.8	17.6	13.5	14.4	14.4	14.5
30.3	12.2	14.1	14.2	14.0	14.8	15.6	14.7	14.1	14.9	16.0	15.0	14.0	14.9	14.0	13.9	13.2	13.5	15.4	12.9	13.0	14.2	14.9	13.7	17.5	13.5	14.4	14.4	14.4
31.1	12.6	14.2	14.4	14.2	15.1	15.8	15.1	14.2	15.0	16.3	15.3	14.1	15.2	14.0	14.0	13.4	13.5	15.5	12.9	13.1	14.3	14.8	13.6	17.4	13.5	14.4	14.4	14.4
31.2	12.8	15.4	16.6	16.1	16.9	16.8	16.3	15.4	15.6	16.8	16.0	14.7	15.7	14.7	14.7	14.0	14.2	15.7	13.0	13.5	14.3	15.0	13.6	17.3	13.5	14.4	14.4	14.4
32.1	12.4	16.0	15.9	16.7	17.2	17.0	---	15.7	15.8	17.0	16.1	14.9	15.9	14.9	14.9	13.9	14.2	15.8	13.0	13.4	14.4	15.0	13.8	17.2	13.5	14.4	14.4	14.4

*See Fig. 24.

TABLE VII
SUMMARY OF 45-DEG CHANNEL ELECTRICAL MEASUREMENTS
a. Channel-to-Load Bank

Run Number	Magnet Field Strength, gauss	Magnet Current, amp	Load Bank Config.	Time, t_1, sec	Current, Channel-to-Load Bank, amp														
					Element A_B I2	Element B_B I4	Element C_B I6	Element D_B I8	Element E_B I10	Element F_B I12	Element G_B I14	Element H_B I16	Element 1 I18	Element 3 I20	Element 2 I22	Element 7 I24	Element 8 I26	Element 11 I28	Element 13 I30
16.1									Aerodynamic Checkout Firings										
16.3																			
17.1																			
17.2	10,000	428	1	13.2	-0	-2	-4	-1	-2	-2	-4	-1	-1	-1	-1	0	0	-2	-1
18.1	12,900	650	1	14.1	-2	-3	-6	-2	-2	-3	-5	-3	-3	0	-2	0	0	-2	-2
18.2	20,000	1200	1	14.3	-3	-4	-10	-4	-4	-5	-8	-4	-6	-1	-4	-2	-2	-2	-2
19.2	16,000	875	2	15.2	-0	-2	-7	-3	0	-0	-4	-3	-4	0	-1	-2	0	-2	-2
19.3	20,000	1200	2	16.2	-5	-7	-14	-7	---	-10	-10	-6	-5	-2	-2	-3	-2	-2	-2
20.1	20,000	1200	3	15.8	-0	-1	0	0	-1	0	-1	0	0	0	0	-1	0	0	-2
20.2	15,000	650	3	15.0	-2	-3	-7	-2	-2	-4	-5	-2	-3	0	-1	-1	-1	-2	-2
20.3	18,000	875	3	14.2	-7	-2	-7	-5	-12	-7	-8	-4	-5	-3	-2	-2	-2	-2	-2
20.4	20,000	1200	3	14.6	-5	-6	-10	-4	-7	-8	-6	-4	-2	-2	-3	-3	-2	-2	-2
20.5	17,900	875	3	14.2	-4	-4	-6	-3	-1	-4	-2	-2	-4	-2	-2	-2	0	-1	-2
20.6	20,000	1200	3	14.4	-5	-6	-10	-4	-5	-6	-6	-4	-6	-3	-1	-1	-2	-2	-2
22.1	15,000	650	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	15,000	650	4	14.4	-2	-4	-6	-4	-2	-5	-6	-4	-1	-2	-2	0	0	0	-1
22.3	15,000	650	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	20,000	1200	4	14.4	-6	-8	-14	-7	-9	-3	-10	-6	-3	-6	-3	-4	-4	-2	-3
22.5	15,000	650	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	20,000	1200	4	14.2	-8	-9	-16	-8	-9	---	-6	-5	-6	-4	-5	-6	-4	-1	-2
22.7	20,000	1200	4	14.2	-10	-8	-15	-4	-8	-8	-9	-8	-8	-3	-4	-2	-3	0	-1
22.8	20,000	1200	4	14.8	-9	-10	-11	-8	-6	-6	-6	-5	-7	-4	-4	-3	-2	-2	-1
23.1	15,000	650	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.2	20,000	1200	5	16.6	-6	-8	-6	-7	---	-2	-4	---	-8	-4	-2	-2	-2	0	-1
23.3	20,000	1200	5	16.6	-5	-2	-8	-4	-2	-4	-8	-2	-4	-4	-2	-2	-2	-2	-2
23.4	20,000	1200	5	16.6	-0	-5	-8	-4	-4	-6	-6	-5	-12	-2	-1	-2	-2	-2	-2
23.5	20,000	1200	5	15.8	-5	-4	-8	-4	-4	-6	-6	-2	-6	-2	-2	-2	-2	-2	-2
23.6	20,000	1200	5	16.6	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0
24.1	20,000	1200	5	15.8	0	-1	-2	-1	-1	0	-2	0	-2	-1	-1	-1	0	0	-2
24.2	20,000	1200	5	15.6	-2	-4	-7	-9	-8	-8	-0	-5	-2	-2	-1	-2	-2	-1	-2

a. Continued

TABLE VII (Continued)

Run Number	Time, t_2, sec	Current, Channel-In-Load Bank, amp															
		Element 15 132	Element 17 134	Element 19 136	Element 21 138	Element 23 135	Element 25 137	Element 27 139	Element 29 141	Element 31 143	Element 31 145	Element 33 147	Element 35 149	Element 37 151	Element 39 153	Element 41 155	Element 43 157
16.1									Aerodynamic Checkout Firings								
16.3																	
17.1																	
17.2	13.2	-2	3	2	1	1	1	0	0	-1	-4	0	-1	-1	-1	-2	-1
18.1	14.1	-1	2	0	4	1	1	0	0	0	-4	0	0	0	-1	-1	0
18.2	14.2	-1	3	1	1	0	2	2	0	-1	-2	0	0	0	2	-2	3
19.2	15.2	-8	-2	0	0	0	2	2	2	0	4	1	0	0	1	-2	2
19.2	15.2	-1	-1	0	0	1	2	2	2	1	2	1	0	1	2	0	2
20.1	15.8	-1	-2	0	0	1	0	0	1	0	4	0	0	0	0	0	0
20.2	15.0	0	-15	0	0	2	3	3	3	0	2	0	1	2	1	2	0
20.2	14.2	0	-11	0	-1	2	3	2	2	0	3	0	0	2	2	0	2
20.4	14.6	-1	-28	-2	0	2	4	2	2	1	4	0	0	2	1	0	2
20.5	14.2	0	-17	0	-1	1	2	1	2	0	3	0	1	2	0	1	1
20.6	14.4	0	-28	0	0	3	2	1	1	1	4	0	0	2	2	0	2
22.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	14.4	0	-2	0	0	1	2	1	---	0	0	1	0	0	0	0	0
22.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	14.4	-1	-2	-2	0	1	4	2	---	8	0	0	0	2	4	1	3
22.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	14.2	-1	-1	-1	0	2	4	2	---	7	0	0	0	0	3	0	5
22.7	14.2	-1	-3	-2	0	1	3	0	---	18	8	1	0	0	2	0	2
22.8	14.6	-1	-1	-2	0	0	3	0	---	16	0	0	0	1	2	1	1
23.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.2	16.6	0	-2	-2	0	3	3	4	3	2	0	0	1	2	5	0	-4
23.2	16.8	0	0	-1	0	2	4	1	2	0	0	0	0	2	2	2	50
23.4	16.6	0	-1	0	0	2	3	1	1	1	0	1	1	2	2	3	46
23.5	15.8	0	0	0	0	1	3	0	1	1	1	0	1	2	2	2	45
23.6	16.6	-1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
24.1	15.8	1	0	0	0	1	0	0	1	0	0	0	0	0	1	2	2
24.2	15.6	-1	-1	0	0	2	3	2	2	0	0	1	1	1	3	2	5

a. Concluded

TABLE VII (Continued)

Run Number	Time, t_2, sec	Current, Channel-to-Load Bank, amp											
		Element 45 I_{59}	Element 47 I_{61}	Element 49 I_{63}	Element 51 I_1	Element A_T I_3	Element B_T I_5	Element C_T I_7	Element D_T I_9	Element E_T I_{11}	Element F_T I_{13}	Element G_T I_{15}	Element 21-23 I_{69}
16.1						Aerodynamic Checkout Firings							
16.3													
17.1													
17.2	13.2	0	0	0	-3	0	-4	-2	-3	-2	0	-1	---
18.1	14.1	0	0	2	7	2	8	3	6	4	4	4	---
18.2	14.3	5	3	4	10	4	10	4	7	4	6	6	---
19.2	15.2	1	2	0	8	3	4	2	7	0	2	3	48
19.3	15.2	5	3	4	8	4	9	2	10	0	2	---	48
20.1	15.8	0	0	0	0	2	2	0	1	0	1	1	3
20.2	15.0	0	0	0	4	4	7	4	6	6	6	7	40
20.3	14.2	0	2	4	8	6	6	4	6	6	4	-3	51
20.4	14.6	2	3	4	8	7	8	4	8	7	7	7	68
20.5	14.2	0	0	1	4	4	6	4	5	5	6	9	41
20.6	14.4	3	3	2	10	6	8	4	7	6	6	1	67
22.1	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	14.4	0	0	1	6	4	7	4	7	6	6	4	42
22.3	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	14.4	2	6	2	9	7	10	4	8	4	2	-12	42
22.5	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	14.2	4	6	8	10	8	10	8	10	---	-14	20	38
22.7	14.2	1	3	4	10	8	23	4	8	9	11	13	88
22.8	14.6	2	2	4	10	6	22	6	7	9	12	16	82
23.1	---	---	---	---	---	---	---	---	---	---	---	---	---
23.2	16.6	16	Pegged Neg	10	10	7	10	4	14	0	7	8	20
23.3	16.6	Pegged Neg	0	4	8	4	6	5	10	4	7	8	57
23.4	16.6	Pegged Neg	0	6	10	6	6	4	8	6	7	7	57
23.5	15.8	Pegged Neg	-2	4	10	5	6	4	9	4	7	8	57
23.6	16.6	0	0	0	0	1	0	0	1	0	0	0	16
24.1	15.8	0	0	1	0	2	2	0	2	0	2	2	12
24.2	15.6	-18	-14	-10	9	9	9	4	10	3	7	8	18

b. Element Top-to-Element Bottom

TABLE VII

Run Number	Time, t_0, sec	Current, Element Top to Element Bottom, amp																		
		Element 1 I17	Element 3 I19	Element 5 I21	Element 7 I23	Element 9 I26	Element 11 I27	Element 13 I30	Element 15 I31	Element 17 I33	Element 19 I65	Element 21 I67	Element 23 I36	Element 25 I38	Element 27 I40	Element 29 I42	Element 31 I44	Element 33 I46	Element 35 I48	Element 37 I50
16.1										Aerodynamic Checkout Firings										
16.3																				
17.1																				
17.2	13.2	2	4	3	4	4	3	4	5	3	-2	4	3	3	2	3	3	4	4	5
18.1	14.1	7	7	6	6	7	6	0	7	5	0	6	6	7	4	5	8	7	5	5
18.2	14.3	10	10	8	10	10	10	10	10	10	0	10	10	11	9	10	10	10	10	9
19.2	15.2	8	6	7	8	7	6	8	8	7	8	6	8	8	7	7	6	8	7	6
19.3	15.2	9	10	10	10	11	10	11	10	9	10	8	10	11	9	10	10	10	9	8
20.1	15.8	0	0	0	1	2	0	1	0	0	2	0	0	0	1	0	0	0	0	0
20.2	15.0	7	8	6	6	7	6	[illegible]	7	5	7	4	6	7	6	6	6	8	6	5
20.3	14.7	8	9	8	9	9	6	10	9	8	9	8	9	10	11	9	8	9	9	7
20.4	14.8	10	10	12	10	12	10	12	10	10	11	8	10	12	10	10	8	10	10	8
20.5	14.2	5	5	4	5	6	4	6	6	4	6	4	5	6	4	5	5	5	6	4
20.6	14.4	10	10	10	10	11	10	12	10	10	11	9	10	12	10	10	9	10	10	8
22.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	14.4	6	6	8	6	8	6	5	7	5	6	4	6	8	7	6	7	8	6	5
22.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	14.4	8	10	9	9	12	10	12	10	10	10	8	10	11	10	10	10	---	9	9
22.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	14.2	9	10	10	9	12	10	12	10	10	10	9	10	11	9	10	10	10	9	8
22.7	14.2	10	10	10	8	12	10	10	10	10	10	9	10	12	10	10	10	10	9	11
22.8	14.6	8	9	8	8	10	8	10	9	8	9	7	8	10	8	8	8	8	8	8
23.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.2	15.6	0	8	8	9	10	8	10	10	9	10	8	10	10	10	10	10	8	8	8
23.3	15.6	10	8	8	9	10	8	10	10	10	10	8	10	12	10	10	10	8	8	8
23.4	15.6	10	8	10	10	12	8	12	11	10	10	10	10	12	10	10	10	9	8	9
23.5	15.8	10	8	10	10	12	9	12	10	10	10	10	10	12	10	10	10	8	9	10
23.6	15.8	0	0	0	1	0	2	1	0	0	3	0	0	0	0	0	0	0	0	0
24.1	15.8	2	0	1	2	2	1	2	2	0	1	2	1	1	1	1	2	0	1	1
24.2	15.8	10	8	8	9	10	8	10	10	8	10	10	8	10	9	9	8	8	8	8

TABLE VII (Continued)

b. Concluded

Run Number	Time, t_2, sec	Current, Element Top-to-Element Bottom, amp						
		Element 39 I52	Element 41 I54	Element 43 I56	Element 45 I58	Element 47 I60	Element 49 I62	Element 51 I64
16.1				Aerodynamic Checkout Firings				
16.3								
17.1								
17.2	13.2	4	2	2	2	4	2	2
18.1	14.1	7	5	---	5	6	4	4
18.2	14.3	10	8	---	7	7	4	4
19.2	15.2	8	5	7	6	7	3	4
19.3	15.2	10	8	8	8	5	4	5
20.1	15.8	0	0	0	0	0	1	0
20.2	15.0	7	6	6	6	6	3	3
20.3	14.2	10	8	8	8	8	4	4
20.4	14.6	10	8	8	8	8	4	5
20.5	14.2	5	4	4	4	4	2	2
20.6	14.4	10	9	8	8	7	3	5
22.1	---	---	---	---	---	---	---	---
22.2	14.4	5	5	5	4	5	4	4
22.3	---	---	---	---	---	---	---	---
22.4	14.4	8	8	10	7	8	6	5
22.5	---	---	---	---	---	---	---	---
22.6	14.2	9	8	8	7	6	4	2
22.7	14.2	10	7	8	8	8	6	4
22.8	14.6	8	6	7	8	7	6	4
23.1	---	---	---	---	---	---	---	---
23.2	16.6	8	8	7	5	---	2	4
23.3	16.6	10	8	8	8	4	4	4
23.4	16.6	12	8	9	9	2	4	5
23.5	15.8	11	9	9	8	---	3	4
23.6	16.6	0	0	0	0	0	0	0
24.1	15.8	0	1	0	0	0	0	0
24.2	15.6	8	8	7	4	17	13	20

c. Load Bank Voltages

TABLE VII (Continued)

Run Number	Time, t_f, sec	Load Bank Voltages, v																			
		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20
		Element A_H—Element D_H V2	Element B_H—Element C_H V4	Element C_H—Element D_H V6	Element D_H—Element E_H V8	Element E_H—Element F_H V10	Element F_H—Element G_H V12	Element G_H—Element H_H V14	Element H_H—Element 1 V16	Element 1—Element 3 V18	Element 3—Element 5 V20	Element 5—Element 7 V22	Element 7—Element 9 V24	Element 9—Element 11 V26	Element 11—Element 13 V28	Element 13—Element 15 V30	Element 15—Element 17 V32	Element 17—Element 19 V34	Element 19—Element 21 V36	Element 21—Element 23 V38	Element 23—Element 25 V40
16.1	Aerodynamic Checkout Firings																				
16.3																					
17.1																					
17.2	13.2	1	1	0	1	2	2	4	5	8	7	8	8	3	7	8	5	7	4	7	7
18.1	14.1	---	2	0	2	4	4	5	10	13	14	15	14	14	15	16	14	14	10	16	15
18.2	14.3	---	2	2	4	6	8	8	17	22	12	28	24	24	26	25	24	26	24	28	28
19.2	15.2	0	2	1	3	4	4	0	2	7	8	5	10	9	10	12	8	10	11	10	11
19.3	15.2	0	3	4	8	3	-3	0	6	5	7	8	10	10	16	12	10	10	13	12	11
20.1	15.8	0	3	0	0	1	0	1	1	3	3	2	3	3	3	4	2	2	2	2	3
20.2	15.0	0	2	1	3	3	4	5	11	14	14	15	15	14	16	18	15	15	16	18	18
20.3	14.9	0	2	2	4	-2	-1	1	3	8	8	9	10	9	18	12	10	11	11	12	10
20.4	14.6	0	2	3	4	5	5	8	12	22	24	26	24	23	27	28	27	28	25	28	28
20.5	14.7	0	2	1	2	3	4	5	10	14	15	16	15	14	16	17	15	17	19	17	18
20.6	14.4	0	2	2	4	5	8	8	18	21	22	20	22	28	27	27	26	28	27	28	27
22.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	14.4	0	1	0	0	---	2	1	6	7	8	6	8	7	8	10	5	10	---	9	8
22.3	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	14.4	0	1	0	0	---	4	1	4	4	6	7	6	8	8	10	3	10	---	10	10
22.5	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	14.2	0	1	0	0	---	-2	0	2	3	3	5	7	6	7	10	7	8	---	10	8
22.7	14.2	0	0	0	0	---	4	6	12	14	15	17	20	19	19	20	20	20	18	22	20
22.8	14.6	0	1	0	0	---	4	4	10	14	14	16	18	18	18	19	22	20	17	20	18
23.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.2	15.6	0	4	3	8	-6	8	10	---	8	3	5	8	8	8	9	6	10	10	10	10
23.3	15.6	0	2	2	4	9	0	8	20	23	27	28	30	28	30	31	30	31	32	32	30
23.4	15.6	0	3	2	3	6	7	9	20	28	29	30	30	30	31	32	31	32	33	34	30
23.5	15.8	0	2	2	4	6	7	8	20	25	33	30	30	32	30	33	32	32	32	32	30
23.6	15.4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
24.1	15.3	0	2	0	1	2	1	2	4	5	6	6	6	6	6	7	6	4	7	8	8
24.2	15.6	0	-2	-4	-4	-3	-2	0	3	3	6	6	8	8	7	10	8	10	10	10	10

c. Concluded

TABLE VII (Concluded)

Run Number	Time, sec	Load Bars Voltages, v																				
		R21 Element 11– Element 27 V15	R22 Element 21– Element 29 V39	R23 Element 30– Element 31 V41	R24 Element 21– Element 33 V43	R25 Element 33– Element 35 V45	R26 Element 35– Element 37 V47	R27 Element 1– Element 19 V49	R28 Element 21– Element 41 V51	R29 Element 45– Element 22 V53	R30 Element 45– Element 45 V45	R31 Element 45– Element 47 V57	R49 Element 47– Element 49 V59	R32 Element 49– Element 51 V54	R34 Element 51 Element A_T V56	R35 Element A_T– Element B_T V1	R36 Element B_T– Element C_T V4	R37 Element C_T– Element D_T V6	R38 Element D_T– Element E_T V7	R39 Element E_T– Element F_T V9	R40 Element F_T– Element G_T V11	R41 Element G_T– Element H_T V12
15.1		Aerodynamic Checkout Firings																				
15.2																						
17.1																						
18.2	14.7	7	7	6	7	10	8	1	7	9	0	0	9	9	0	---	2	0	0	1	0	0
18.1	15.1	16	12	11	11	11	11	15	15	14	14	14	14	12	8	---	1	2	1	8	---	---
19.2	14.5	27	25	14	25	24	26	25	24	23	41	41	20	17	7	---	4	3	3	2	---	---
19.1	15.2	12	9	12	10	12	10	10	6	8	12	2	9	7	---	1	1	0	-1	12	-14	0
19.3	15.3	12	11	10	10	12	10	10	10	9	8	8	5	4	---	0	0	-2	3	14	-19	0
20.1	16.2	3	3	0	3	4	1	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0
20.2	15.0	18	11	16	14	11	15	14	14	14	19	18	14	4	2	1	0	2	1	0	0	0
20.3	14.2	12	11	10	11	12	10	10	10	0	10	0	8	7	2	1	0	0	0	0	0	0
20.4	14.4	28	24	24	24	25	24	22	12	22	22	30	20	18	8	4	4	3	3	2	0	0
20.5	14.2	17	18	18	17	18	14	14	19	18	27	14	18	12	3	4	3	3	8	3	0	0
20.6	15.1	28	21	20	28	19	21	12	11	22	24	31	20	12	7	3	4	2	1	4	0	0
22.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.2	14.8	8	8	1	8	6	7	9	---	7	8	8	8	9	---	2	3	2	---	0	0	0
22.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.4	14.6	10	9	8	9	8	9	6	---	7	9	9	6	6	---	0	0	4	---	0	0	0
22.5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
22.6	14.8	8	7	---	7	7	9	6	8	9	7	6	1	8	---	0	0	0	---	0	0	0
23.1	14.8	20	18	10	19	19	19	18	16	13	16	11	14	11	---	8	4	2	---	0	9	0
23.2	14.4	20	14	17	19	17	14	13	18	16	10	18	15	11	3	2	8	1	---	0	0	0
23.3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.4	14.9	11	8	10	10	10	9	19	8	9	10	4	2	22	19	4	2	3	4	8	4	0
23.5	18.9	24	19	08	20	19	26	29	26	31	24	1	23	24	30	9	1	1	8	1	0	0
23.6	18.9	11	14	20	20	23	17	29	28	25	24	4	23	24	10	8	1	4	8	2	0	0
23.9	12.8	23	26	20	19	19	27	45	27	24	23	4	16	07	10	0	1	4	4	1	0	0
23.4	14.0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.1	11.0	5	5	1	0	0	5	4	4	4	1	1	4	5	1	1	1	0	2	1	0	0
24.2	15.0	10	8	10	9	0	0	9	4	9	4	8	28	22	10	4	7	0	4	2	0	0

TABLE VIII
SUMMARY OF HALL CHANNEL ELECTRICAL MEASUREMENTS
a. Channel-to-Load Bank

Run Number	Magnet Field Strength, gauss	Magnet Current, amp	Load Bank Config.	Time, t_2, sec	Current, Channel-to-Load Bank, amp															
					Element 1 I2	Element 2 I4	Element 3 I6	Element 4 I8	Element 5 I10	Element 6 I12	Element 7 I14	Element 9 I16	Element 11 I18	Element 13 I20	Element 15 I22	Element 17 I24	Element 19 I26	Element 21 I28	Element 23 I30	Element 37 I37
15.1					Aerodynamic Checkout Firings															
15.2																				
15.3																				
15.4																				
25.1	20,000	1200	8	No Data Available																
25.2	20,000	1200	8	No Data Available																
26.1	20,000	1200	8	12.2	-18	-9	-8	-2	-4	-8	-4	0	-1	---	0	0	0	0	---	0
26.2	20,000	1200	8	12.8	-19	8	8	6	---	-5	-6	0	0	---	0	0	0	0	---	0
27.1	20,000	1200	8	16.8	-20	-9	-4	-3	-5	-6	-8	0	-2	-1	0	0	0	0	-1	0
27.2	20,000	1200	8	15.8	-20	8	8	4	-5	-4	-8	0	-1	-1	0	0	0	0	-1	0
27.3	20,000	1200	8	15.8	-22	-9	-8	-4	-8	-4	-10	0	-2	-1	0	0	0	0	-2	0
27.4	15,000	850	8	15.6	-14	-8	-4	-4	-4	-2	-9	0	-2	-1	-1	0	0	0	-1	0
28.1	20,000	1200	9	15.8	-22	-10	-8	4	4	-1	-2	0	0	0	0	0	0	0	-1	0
28.2	20,000	1200	9	15.4	-21	-10	-6	-4	-4	-1	-3	0	-1	-1	0	0	0	0	-1	0
28.3	20,000	1200	9	15.6	-22	-10	-4	4	4	0	4	0	2	-1	2	0	0	0	-1	0
28.4	0	0	9	17.4	0	0	0	0	0	0	0	-1	-2	0	-1	0	0	0	-1	0
29.2	20,000	1200	10	15.2	-4	-4	-4	0	-2	0	-4	0	-1	-1	0	0	0	0	-1	0
30.2	20,000	1200	10	12.8	0	-6	-4	0	-3	0	-4	0	-2	1	0	0	0	0	-1	0
30.3	20,000	1200	10	12.2	4	4	-6	-2	-3	0	-4	0	-1	-1	0	0	0	0	-1	0
31.1	20,000	1200	11	12.6	-2	-4	-3	-3	-2	0	-3	0	-1	-1	0	0	0	0	-1	0
31.2	20,000	1200	11	12.8	-12	-6	-3	-2	-1	0	-2	0	-1	-1	0	0	0	0	-1	0
32.1	20,000	1200	12	12.4	-2	-4	0	-2	-1	-1	-3	0	-1	-1	0	0	0	0	-1	0

a. Concluded

TABLE VIII (Continued)

Run Number	Time, t_2, sec	Current, Channel-to-Load Bank, amp															
		Element 39 I39	Element 41 I41	Element 43 I43	Element 45 I45	Element 47 I47	Element 49 I49	Element 51 I51	Element 53 I53	Element 54 I55	Element 55 I57	Element 56 I59	Element 57 I61	Element 58 I63	Element 59 I65	Element 60 I67	Element 7 I69
15.1								Aerodynamic Checkout Firings									
15.2																	
15.3																	
15.4																	
25.1	No Data Available																
25.2	No Data Available																
26.1	12.2	0	0	1	0	0	0	0	2	---	31	8	---	4	9	10	54
26.2	12.6	0	0	0	0	0	0	0	5	---	30	10	---	3	9	10	57
27.1	18.0	0	0	0	1	0	0	0	6	4	4	6	6	4	10	13	58
27.2	15.0	0	0	0	1	1	0	0	8	4	6	5	7	4	10	15	61
27.3	18.0	0	0	0	1	0	0	0	9	6	4	5	8	4	10	16	63
27.4	15.6	0	0	0	1	0	0	0	4	2	3	4	6	4	8	15	47
28.1	15.8	0	0	0	0	0	0	0	4	3	3	4	8	4	7	17	53
28.2	15.4	0	0	0	0	0	0	0	4	4	3	4	6	8	9	18	51
28.3	15.6	0	0	0	0	0	0	0	4	4	4	4	8	5	8	17	53
28.4	17.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.2	15.2	0	0	0	1	0	0	0	1	3	2	2	2	2	4	3	20
30.2	12.8	0	0	0	0	0	0	0	3	4	2	4	4	4	8	12	17
30.3	12.7	0	0	0	0	0	0	0	3	4	2	2	4	0	6	3	24
31.1	12.6	0	0	0	0	0	0	0	3	2	1	2	2	0	4	2	16
31.2	12.8	0	0	0	0	0	0	0	3	3	2	0	3	2	5	6	28
32.1	12.4	0	0	0	0	0	0	0	2	2	0	0	1	0	2	1	10

b. Element Top-to-Element Bottom

TABLE VIII (Continued)

Run Number	Time, t_2, sec	Current, Element Top-to-Element Bottom, amp																	
		Element 1 I_1	Element 2 I_3	Element 3 I_5	Element 4 I_7	Element 5 I_9	Element 6 I_{11}	Element 7 I_{13}	Element 9 I_{15}	Element 11 I_{17}	Element 13 I_{19}	Element 15 I_{21}	Element 17 I_{23}	Element 19 I_{25}	Element 21 I_{27}	Element 23 I_{29}	Element 25 I_{31}	Element 27 I_{32}	Element 29 I_{33}
15.1										Aerodynamic Checkout Firings									
15.2																			
15.3																			
15.4																			
25.1										No Data Available									
25.2										No Data Available									
26.1	12.7	20	18	---	10	12	11	12	---	7	6	7	10	---	8	10	10	10	9
26.2	12.8	20	17	---	11	12	10	12	---	7	6	6	12	---	8	10	10	10	9
27.1	16.0	24	10	12	12	14	10	14	10	8	6	9	15	10	10	11	12	10	10
27.2	15.0	28	10	14	12	16	11	14	11	10	11	12	14	12	12	12	13	10	11
27.3	15.0	28	20	14	12	15	12	14	11	10	12	12	14	13	12	13	14	11	11
27.4	15.6	18	18	12	10	12	11	12	10	10	9	10	10	10	10	10	10	10	10
28.1	15.8	27	20	15	14	15	11	14	13	12	14	14	16	15	13	16	13	12	11
28.2	15.4	26	20	14	14	14	12	12	12	12	14	14	14	14	13	14	12	10	10
28.3	15.6	26	20	14	14	14	10	13	13	12	14	12	14	13	12	14	13	12	10
28.4	17.4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.2	15.3	11	14	10	10	10	0	10	10	8	8	8	14	10	8	11	10	8	8
30.2	13.1	7	13	11	8	10	9	12	10	10	3	9	15	11	8	12	11	8	8
30.3	12.2	10	13	12	10	12	10	12	10	10	2	10	16	13	10	14	14	10	9
31.1	12.6	10	14	10	12	11	10	12	10	10	2	11	14	12	10	14	13	10	8
31.2	12.8	20	17	12	14	12	10	12	12	12	3	13	16	14	12	16	14	11	9
32.1	12.4	11	16	10	13	12	10	11	11	10	2	13	15	14	11	15	14	11	9

TABLE VIII (Continued)

b. Concluded

Test Number	Time, t_j, sec	Current, Element Top to Element Bottom, amp																		
		Element 31 134	Element 33 135	Element 35 138	Element 37 138	Element 39 140	Element 41 142	Element 43 144	Element 45 146	Element 47 148	Element 49 150	Element 51 152	Element 53 154	Element 54 156	Element 55 158	Element 56 160	Element 57 162	Element 58 164	Element 59 166	Element 60 168
15.1		Aerodynamic Checkout Firings																		
15.2																				
15.3																				
15.4																				
25.1	No Data Available																			
25.2	No Data Available																			
26.1	12.2	8	---	10	8	---	8	10	9	8	---	3	3	4	4	---	2	3	1	1
26.2	12.8	8	---	10	8	---	8	10	10	8	---	6	5	4	4	---	3	2	2	2
27.1	18.0	10	14	10	12	8	10	12	10	10	10	7	4	8	8	8	4	3	3	0
27.2	15.0	12	14	10	12	9	10	12	11	10	11	10	6	8	8	8	8	4	4	2
27.3	15.0	12	14	10	11	10	11	14	10	10	10	8	4	10	6	8	6	4	4	3
27.4	15.6	10	11	10	11	9	10	13	20	10	10	8	8	8	7	8	8	4	4	3
28.1	15.9	13	14	11	17	10	17	14	12	13	12	10	9	10	8	9	8	4	4	3
28.2	15.4	13	13	11	12	10	13	14	17	10	12	10	9	10	8	8	8	3	4	3
28.3	15.4	13	13	10	13	10	12	14	12	12	13	10	9	10	9	9	7	4	4	4
28.4	17.4	0	1	0	0	0	0	0	-1	0	1	0	0	0	0	0	0	0	0	0
29.2	15.2	8	12	8	10	8	8	10	10	8	8	6	6	6	8	4	4	3	2	3
30.2	12.6	10	14	10	10	8	8	10	11	8	9	7	6	8	8	3	4	2	1	25
30.3	13.3	13	14	10	11	9	8	13	11	9	10	7	7	7	8	4	5	4	4	3
31.1	13.6	11	14	11	10	10	9	11	10	10	10	8	8	8	7	4	8	4	4	4
31.2	12.8	13	13	13	12	10	11	13	11	10	11	8	8	9	8	5	6	3	4	4
32.1	13.4	13	14	12	11	10	12	13	11	11	12	8	10	10	8	8	7	5	4	5

c. Load Bank Voltages

TABLE VIII (Concluded)

Run Number	Time, t_2, sec	Load Bank Voltage, v													
		R1	R2	R3	R4	R5	R6	R Center	R30	R31	R32	R33	R34	R35	R36	R Total
		Element 1— Element 2 V2	Element 2— Element 3 V4	Element 3— Element 4 V6	Element 4— Element 5 V8	Element 5— Element 6 V10	Element 6— Element 7 V12	Element 7— Element 53 V62	Element 53— Element 54 V63	Element 54— Element 55 V65	Element 55— Element 56 V67	Element 56— Element 57 V69	Element 57— Element 58 V64	Element 58— Element 59 V66	Element 59— Element 60 V68	Element 1— Element 60 V61
15.1								Aerodynamic Checkout Firing								
15.2																
15.3																
15.4																
25.1	No Data Available															
25.2	No Data Available															
26.1	12.2	0	2	2	3	4	5	100	3	4	1	0	1	1	0	---
26.2	12.8	0	3	2	3	6	4	100	3	3	0	0	0	1	0	---
27.1	16.0	1	3	2	3	5	4	100	4	4	3	2	1	2	0	130
27.2	15.0	0	3	3	4	6	6	100	4	4	2	2	1	1	0	130
27.3	15.0	0	3	2	3	6	5	110	4	4	2	2	0	2	0	140
27.4	15.6	1	2	2	2	4	4	80	3	4	2	2	0	1	1	100
28.1	15.6	0	3	3	3	6	4	220	3	4	2	2	0	1	0	260
28.2	15.4	0	4	3	4	6	4	210	3	4	2	2	0	2	0	240
28.3	15.8	1	4	2	4	6	4	220	4	4	3	2	1	1	0	240
28.4	17.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.2	15.2	0	2	1	2	4	3	150	3	2	2	2	0	1	0	200
30.2	12.6	0	2	1	2	4	3	160	1	2	1	0	0	0	0	210
30.3	12.2	0	2	1	3	5	4	200	3	3	1	2	0	1	0	320
31.1	12.6	0	2	1	3	5	4	210	1	3	1	2	0	0	0	320
31.2	12.8	2	5	4	6	0	8	350	5	6	3	4	2	2	0	570
32.1	12.4	0	3	2	3	6	6	220	4	4	2	2	0	0	0	340

TABLE IX
TYPICAL CHANNEL TEMPERATURE VARIATIONS WITH TIME
a. 45-deg Channel

Run Number	Gated Time, sec	Channel Temperature, °C																			
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20
17.1	9.04	20	20	20	20	20	20	20	20	40	---	---	20	10	20	0	10	20	20	20	0
	10.31	20	20	20	20	20	20	20	20	30	---	---	20	10	20	10	10	10	20	20	10
	11.56	40	50	40	70	50	50	50	40	60	---	---	60	30	50	40	30	30	40	10	10
	12.85	110	100	100	100	80	100	80	70	110	---	---	90	80	100	70	70	70	60	20	10
	14.09	130	130	120	150	120	160	110	100	170	---	---	180	100	100	100	100	100	110	20	30
	15.34	130	160	150	170	140	210	130	100	210	---	---	220	100	140	100	140	120	110	30	60
	16.57	160	190	200	190	160	240	140	140	260	---	---	270	150	150	130	160	150	130	50	80
	17.82	160	190	180	190	150	280	150	160	320	---	---	300	150	160	140	190	160	150	80	90
	19.04	170	170	150	170	140	280	140	130	300	---	---	290	130	120	120	190	120	130	120	120
	20.29	140	160	160	160	130	280	120	120	300	---	---	300	120	120	100	200	110	140	200	120
	21.52	120	150	140	160	120	270	110	120	270	---	---	280	100	120	100	190	100	140	220	130
	22.77	130	130	120	160	120	260	100	100	270	---	---	270	100	110	100	180	100	160	260	140
	23.99	130	120	120	170	110	240	100	100	280	---	---	270	110	120	110	180	100	140	280	130
	26.58	120	120	120	140	110	250	100	120	240	---	---	250	100	100	100	170	100	130	350	100
20.8	9.58	60	60	60	60	60	60	60	70	80	---	90	70	60	80	70	50	70	100	40	20
	10.60	60	60	80	70	70	70	60	90	90	---	90	80	60	80	70	50	70	100	40	20
	11.59	90	90	100	100	100	100	90	90	110	---	120	110	90	100	100	80	100	100	40	20
	12.59	110	130	150	140	140	140	120	120	140	---	150	160	140	140	120	100	140	130	50	20
	13.60	130	160	180	190	170	180	160	160	190	---	180	200	160	190	150	140	180	160	80	40
	14.58	150	190	200	200	200	220	180	180	220	---	200	240	190	200	170	170	200	190	100	80
	15.59	160	200	230	220	210	260	200	200	260	---	210	270	200	220	190	200	220	210	100	110
	16.60	180	210	240	240	230	300	220	230	300	---	220	310	220	240	200	230	230	230	120	120
	17.57	200	240	260	260	240	320	230	230	330	---	240	340	230	250	210	260	250	240	150	130
	19.58	230	270	290	290	270	400	240	260	400	---	260	410	250	280	230	310	260	270	210	130
	20.56	240	290	300	300	280	420	240	280	420	---	280	440	260	280	240	330	280	280	260	130
	21.57	240	270	300	300	280	450	240	280	440	---	280	450	250	270	240	350	270	290	320	130
	22.55	230	260	280	270	260	---	230	270	430	---	260	450	340	250	230	350	270	290	380	210
	23.52	220	240	260	260	240	---	220	250	430	---	260	450	220	240	200	350	240	300	440	270
	24.52	200	230	240	240	240	---	200	240	430	---	230	440	210	230	210	340	230	280	480	300
	25.50	200	230	240	240	230	---	200	230	430	---	230	440	210	200	200	340	220	280	540	310
	26.49	200	200	230	230	220	---	200	220	410	---	230	430	200	220	200	340	220	280	580	320

b. Hall Channel

TABLE IX (Concluded)

Run Number	Gated Time, sec	Channel Temperature, °C																	
		T1	T3	T4	T5	T6	T7	T8	T9	T10	T11	T13	T14	T15	T16	T17	T18	T19	T20
28.3	4.69	---	40	50	50	40	60	40	80	80	70	60	60	60	70	80	90	20	20
	5.70	---	40	60	50	40	60	40	80	60	60	60	60	60	70	80	90	20	20
	6.71	---	60	60	60	50	80	60	100	80	80	60	80	60	80	80	100	30	20
	7.77	---	80	100	100	100	100	100	120	100	140	80	100	100	100	100	100	30	30
	8.77	60	120	120	120	140	120	160	180	120	160	120	140	120	100	120	120	60	40
	9.79	80	180	160	170	180	160	170	200	160	200	140	180	180	160	180	160	100	40
	10.88	80	220	180	180	320	180	200	240	170	210	160	180	200	160	170	160	130	60
	11.89	90	240	200	200	250	180	210	290	190	230	180	190	230	160	190	180	190	100
	12.89	100	280	200	220	290	190	230	320	210	230	200	220	250	170	210	190	250	120
	13.98	120	300	220	240	320	200	240	340	200	260	200	230	280	180	230	200	320	130
	15.01	120	340	240	260	360	210	270	380	230	200	210	240	320	190	240	200	400	120
	16.02	160	380	250	280	400	230	300	410	240	300	230	280	330	200	260	230	470	140
	17.11	160	400	260	300	400	240	300	430	260	320	240	300	370	210	280	240	550	120
	18.12	160	420	280	320	460	240	320	460	260	350	250	300	400	220	310	250	630	130
	19.12	180	430	280	330	460	280	320	490	280	360	280	320	420	230	320	270	700	160
	20.12	200	460	280	330	460	260	330	500	280	350	280	320	430	230	330	280	750	220
28.4	4.23	40	40	60	60	40	60	60	80	60	---	60	60	40	60	60	60	20	20
	5.20	40	40	80	60	20	60	40	80	80	80	60	60	60	60	60	80	20	20
	6.19	40	40	60	40	40	60	60	---	60	80	40	60	60	60	60	100	20	20
	7.17	40	60	80	80	60	100	80	100	80	100	60	80	80	60	60	100	20	20
	8.14	40	120	100	100	100	100	100	140	100	100	100	100	120	100	100	100	20	20
	9.12	60	160	140	120	160	120	120	180	140	140	120	100	120	100	100	140	40	40
	10.08	60	200	140	140	180	120	120	200	160	---	140	120	140	120	140	160	60	40
	11.05	80	240	160	160	220	140	140	240	160	160	140	140	180	120	140	160	100	80
	12.02	80	280	180	180	240	160	160	240	160	160	160	200	140	160	180	160	120	120
	12.98	80	300	200	200	280	180	180	280	220	200	180	160	220	140	160	200	180	120
	13.95	100	340	200	200	320	180	180	220	180	200	180	180	240	160	180	200	220	140
	14.92	100	360	220	220	340	200	200	340	200	200	200	180	280	160	200	220	280	120
	15.87	100	400	340	220	360	200	200	360	200	220	220	200	300	180	200	240	320	140
	16.84	---	420	240	240	400	220	220	400	220	220	200	200	300	180	220	240	380	200
	17.80	180	480	260	260	420	220	220	400	220	220	240	200	340	200	220	250	420	240
	18.75	160	460	260	280	440	240	240	420	240	240	220	220	360	200	240	260	460	260

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13 ABSTRACT

A test program was conducted for the University of Tennessee Space Institute on a vertically segmented wall (Hall) and a diagonally segmented wall (45-deg) magnetohydrodynamic generator. The generators were 48 in. in length and had inside dimensions of 2 in. in width, diverging from 4 in. in height at the channel inlet to 6 in. in height at the channel exit. The plasma was provided by a gaseous oxygen/RP-1 combustor with a Mach number 1.6 nozzle. The propellants were seeded with potassium hydroxide dissolved in ethyl alcohol to produce a high ion concentration in the exhaust stream. The generated power was dissipated through a resistor load bank with a variety of parallel and series resistance configurations. Operation conditions varied as follows: combustor chamber pressure = 39 to 48 psia, KOH concentration to 1.3 percent of total propellant weight flow, magnetic field to 20,000 gauss, and load bank resistance from 2.5 to 27 ohms. Tabulations of combustor performance and of the electrical, pressure, and temperature data from the two generator configurations are presented.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
magnetohydrodynamic generators segmented wall generators seeded propellants operating conditions performance temperature data pressure data electrical data						

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